Impact Disaster Preparedness Planning

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[Abstract] Disaster preparedness is the second line of defense for comet or asteroid impact events. If efforts to deflect or destroy the inbound threat fail or if the mitigation window is too short, disaster preparedness may be the only or last line of defense. Disaster preparedness consists of evacuation, sheltering and post impact recovery. In general, the majority of impacts are small, local events with a very limited area of destruction. Under these circumstances, a disaster preparedness plan will be similar to a hurricane evacuation plan. Initially the hurricane is spotted and assessed by aircraft, ships and satellites but its path is initially unknown. As the hurricanes path begins to be defined, the government will issue general warnings covering a large swath of land that might be potentially threatened. Individuals are informed of the threat and begin preparation. As data resolution becomes sufficiently accurate to make projections of where the hurricane will strike land, specific warnings are issued which describe a narrow band of coastline as the target. The affected area is then evacuated. The same approach will occur during a small to medium impact threat. A critical element for implementing disaster preparedness is identification of the point-of-impact with sufficient warning time to allow evacuation & sheltering plans to be implemented. In general, the delay Doppler radar sites at Goldstone and Arecibo are key. These capabilities can reduce trajectory uncertainty to the level required to make very accurate point-of-impact (location/time) predictions. The best course of action to survive an asteroid or comet impact is to evacuate the zone of destruction prior to the time of impact. The zone of destruction is defined as the area that will receive a blast wave 1-psi or greater overpressure and if the impactor strikes the ocean, the area affected by the tsunami. But evacuation may not always be an option. Geological and governmental barriers, point-of-impact uncertainty, limits on modes of transportation and limited time may preclude effective evacuation. Very large impactors (several miles in diameter) may rain destruction over the entire planet. Alternative options include sheltering in pre-existing man-made shelters or natural shelters or the construction of expedient blast shelter to survive the immediate effects of the impact. A 50-psi overpressure blast shelter can offer protection for approximately 98% of the area within the zone of destruction. Both the Soviet Union and the United States developed designs for construction of expedient blast shelters using commonly available material under short execution timeframe for protection against a nuclear threat. These designs should be updated, tested and the construction details incorporated into impact disaster preparedness plans. Large impact events may produce great damage to the infrastructure, making recovery operations extremely difficult and amplifying the level of the disaster. Most of the damage from the 1906 San Francisco earthquake came from the fire that followed. The plan will define steps that can be taken in advance of the impact to minimize secondary damage. Examples are: lowering the water level in major reservoirs/dams, closing off and securing all underground oil/gas mains, taking nuclear reactors off line, and individuals shutting off gas lines to residences. Other pre-impact planning discussed in this paper include: shelter provisioning, relocation of key industries and key assets, managing transportation choke-points, relaxation of border controls, mass migration, alternate evacuation routes, national shelter plan, roles and coordination of federal/state/local government and reliance on individuals & families, and threat mitigation from triggered secondary disasters.

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I. Introduction

FIFTY years of social science research on disasters has shown that panic is rare even when people feel excessive fear. Human nature tends to shine brightest in adversity. People are naturally social. In a disaster, even a global impact catastrophe, individuals will help those nearby, even complete strangers, before saving themselves. Individuals are quite capable of following impact disaster preparedness plans, even in the face of extreme calamity, but the plans must be there.[1]

Disaster preparedness is the second line of defense for comet or asteroid impact events. If efforts to deflect or destroy the inbound threat fail or if the mitigation window is too short, disaster preparedness may be the only or last ditch line of defense. This plan provides a roadmap for dealing with the impact event from a disaster preparedness perspective. Disaster preparedness consists of evacuation, sheltering and post impact recovery. Disaster preparedness planning can greatly reduce fatality rates and enhance recovery time.

II. Scope

When most individuals think about an asteroid or comet impact, they visualize a worst case Hollywood style scenario, an extinction level event. But in reality these great impacts are extremely rare. The normal impact event is much smaller and occurs in greater frequency. Comets and asteroids come in a variety of sizes. The scope of this planning document is to provide a comprehensive approach for the entire range of impact threats.

At the bottom of the range are the small impactors that will be burned up in the atmosphere. The smallest objects are the size of a grain of sand that turn into "shooting stars" as they enter the atmosphere. Larger objects up to 100 feet (30 meters) in diameter produce bolides in the upper levels of the atmosphere. It is estimated that 200,000 tons of this small meteoroidal material bombards the Earth each year.[2] No action is required for these objects because the impactor is small and will be destroyed by the protective nature of the Earth's atmosphere.

The next layer up-the-scale is asteroids and comets ranging in size from approximately 150 feet to 0.6 miles in diameter (50 m – 1.0 km). These impactors can cause local or regional damage. The primary mitigation approach will be to deflect or destroy the impactor. The back-up approach is to evacuate the zone of destruction centered on the point-of-impact. For the purpose of this plan, the zone of destruction is defined as the area subjected to a 1-psi overburst pressure blast wave. And for ocean impacts, the zone of destruction also includes the shorelines that will be affected by tsunami.

The next layer up is the asteroids and comets that range in size from approximately 0.6 miles to 6.0 miles in diameter (1 km – 10 km). These impactors will cause global damage. The primary mitigation approach will be to deflect or destroy the impactor. The back-up approach is to evacuate the immediate area or survive the impact in natural or man-made shelters.

The top layer is a true end-of-the-world scenario. Comets from the Oort cloud can range in size up to several hundreds of miles in diameter. They travel at incredible speeds as they approach the Earth. Great comets and meteors are too large to be destroyed. In general, the best we could hope to accomplish is a partial destruction and deflection of these fragments, such that only a few fragments would successfully strike the Earth. In this approach, the assumption made up front is that the Earth would be impacted by one or more large comet fragments. This destruction/deflection mitigation approach must be augmented with a shelter plan to achieve positive results.

An estimate of the damage area from a meteor impact based on the size of the impactor is provided in the following table.

Devastation Caused by a Meteor Impact of a Given Size

Diameter	Effect	Area of Destruction
50-100 m	Local Destruction	A small city
160 m	Local Destruction	A large city
350 m	Regional Devastation	A small state
500-900 m	Regional Devastation	A country
> 1 km	Global Catastrophe	A continent + global climatic disruption
10 km	Major Extinction Event	Entire Earth

In general, the majority of impacts are small, local events with a very limited area of destruction. Under these circumstances, a disaster preparedness plan will be similar to a hurricane evacuation plan. Initially the hurricane is spotted and assessed by aircraft, ships and satellites but its ultimate path is initially unknown. As the hurricanes path begins to be defined, the government will issue general warnings covering a large swath of land that might be potentially threatened. Individuals are informed of the threat and begin preparation. As data resolution becomes sufficiently accurate to make projections of where the hurricane will strike land, specific warnings are issued which describe a narrow band of coastline as the target. The affected area is then evacuated.

The same approach will occur during a small to medium impact threat. Asteroids and comets are discovered using optical telescopes. Over time, additional optical sightings made during the discovery apparition or later apparitions allow crude predictions about orbital path and impact probability to be made. At some point in time as further sightings from optical telescopes are added into the data set, the asteroid trajectory is assessed to have a substantial probability of impact. At this point, another tool is brought into service. Delay-Doppler radar is used to reduce post-discovery uncertainty and refine the asteroid trajectory. Radar provides several orders of magnitude finer resolution than obtainable from optical telescopes and also provides information on the asteroid density, shape and internal structure. Because the level of uncertainty is reduced dramatically, the probability-of-impact equations begin to produce a very high probability of impact. The threat is recognized and mitigation efforts to deflect or destroy the incoming comet/asteroid are undertaken. If the mitigation effort fails, the next option is to fall back on a second line of defense, evacuation & sheltering. Delay-Doppler radar is a key and critical element for evacuation planning. Only radar can reduce trajectory uncertainty to the level required to make point-of-impact predictions. Radar data will allow a general warning to be issued describing the potential impact site. As the asteroid approaches Earth, the resolution provided by the radar data improves and point-of-impact hazard area narrows in size. A detailed warning is issued and the area is evacuated.

In dealing with this type of threat, the response to a medium to large size asteroid/comet impact must be elevated to the level of a national imperative.

A. Role of Individuals/Families

Most individuals in our society have very strong survival instincts combined with a willingness to help others in need. They will look to the government for accurate threat information, evacuation & shelter guidance, coordination and post-impact assistance. A strong streak of self-reliance is ingrained in our citizens. In a medium to large impact event, individuals and families will have to shoulder a greater share of responsibility for their survival. Government has a part to play but individuals do also. Individuals must be given the freedom to make choices. They must also bear the responsibility for the choices which they make.

B. Roles of Government

Government can provide guidance, an accurate assessment of point-of-impact, evacuation orders, safe zones or public shelters; identify location of available sheltering, guidance on the construction of expedient shelter and emergency disaster relief after the impact. This may require mass migration of people out of cities into the country, out of the coastal areas to inland areas. The role of government includes:

- Mitigating the impact threat by diverting or destroying the incoming asteroid/comet.
- Managing transportation choke-points.
- Creating treaties with adjacent countries to manage mass evacuations under the potential of cataclysmic events. These treaties should be put into place long before any potential threat is identified and should be mutually beneficial to both countries.
- Providing accurate information about the impact event including the time of impact, size of comet, impact point, and status of mitigation success or failure. Refine impact computations as event gets closer.
- Controlling civil unrest and lawlessness.
- Keeping the transportation lanes open.
- Developing preassigned evacuation routes which optimize use of existing road capacity.
- Keeping energy distribution on-line (e.g., electricity, gasoline, gas) until the final hours.
- Closing off and securing all underground oil/gas mains just prior to impact.
- Powering down nuclear power plants.
- Draining water from dams.
- Keeping communications on-line including the Internet. The government may place telephone traffic in a minimized condition, restricting telephone traffic for emergency planning and coordination only.
- Establishing and maintaining a public shelter registry.
- Coordinating migration of people into local communities.
- Relocating existing grain stockpiles (private/public) outside the zone of destruction prior to impact. Transporting, processing, allocating and distributing the grain stockpiles during the recovery phase.
- Constructing specialized Strategic Shelters (plant and animal species survival, knowledge repositories).
- Managing evacuation of critical military/industrial assets and personnel.

- Minimizing price gouging by establishing price controls on key resources. (e.g., corn, wheat, soybeans, plywood, lumber, black plastic, fuel).

III. Threat Assessment (Identify Point-of-Impact, Preliminary Damage Assessment Forecast)

The major threats from an asteroid or comet impact are the shock wave, thermal radiation, debris and electromagnetic effects. If individuals are evacuated outside the 1-psi overburst blast wave, there is a high probability that their lives can be spared from the destruction. In order for this to occur, the point of impact must be determined with a fair degree of accuracy and there must be sufficient warning time to allow full scale evacuations. Knowing the exact point-of-impact for an ocean impact is also critical. This data would allow analysis of the propagation of the ocean shock wave on the surrounding continents in order to project which coastlines would be affected by a resulting tsunami. From this process, reliable coastal evacuation orders could be given.

A critical element for executing a disaster preparedness plan is identification of the point-of-impact/time-of-impact with sufficient warning time to allow evacuation & sheltering. In general, the delay Doppler radar sites at Goldstone and Arecibo are key national asset whose role is critical for applying civil defense measures to the asteroid/comet threat. The two radar telescopes can reduce trajectory uncertainty to the level required to make very accurate point-of-impact (location/time) predictions. These sites are also the only reliable ground-based technique for determining asteroid/comet critical properties: size, shape, density, internal structure and whether the object is a binary system. Using this key asset, scientist will be able to construct dynamic models to simulating the impact and predict the magnitude of the impact events stratified by geographical areas.

In the past, the radar telescopes (Arecibo and Goldstone) have been threatened with funding cuts and the expertise in place to analyze this data has been threatened with reduction, elimination or realignment. Currently the US National Science Foundation (NSF) is phasing out funding for Arecibo and will shut down its operations prior to 2011. Arecibo is the world’s most sensitive radio telescope. A decision to reduce support of this capability undermines the nation's ability to obtain the information needed to predict and mitigate a collision by an asteroid or comet. Radar reconnaissance is as critical to a successful mitigation program as it is to trajectory predictions. And should mitigation efforts fail, this capability is absolutely critical to a second line of defense. The loss of availability to these sites or this expertise will severely limit the ability to define the point-of-impact with sufficient resolution to issue specific warnings and to implement an evacuation plan.

IV. Evacuation

The best course of action to survive an asteroid or comet impact is to evacuate the zone of destruction prior to the time of impact. The zone of destruction in this planning document is defined as the area that will receive a blast wave 1-psi or greater overpressure and if the impactor strikes the ocean, the area affected by the tsunami.

The government should issue evacuation orders as soon accurate point-of-impact and time-of-impact are determined. Individuals should be encouraged to evacuate the affected area immediately if the impact timeline is short (a few days). Individuals may decide to evacuate the zone of destruction completely or evacuate to public shelters capable of withstanding the blast waves or not evacuate and use existing private shelters or construct expedient shelters. The government should provide accurate guidance but should not call for forced evacuations. Rather the government should allow maximum flexibility for individuals and families to execute their individual disaster preparedness plan.

Motor vehicles are the primary means of evacuating the zone of destruction prior to an impact. During evacuations, main highways may easily become hopelessly gridlocked. The government should facilitate evacuation efforts by:

- Managing choke-points.
- Restricting all but essential tractor-trailer rigs from main highways.
- Ensuring gas stations along the evacuation route are refueled.
- Providing timely advice on alternate less congested routes.
- Aiding stranded motorist.
- Evacuating individuals with no means of transport.

Individuals should facilitate evacuation efforts by:

- Physically moving disabled vehicles off to the side of the roadway.
- Redirecting traffic around gridlocked areas.
- Evacuating individuals stranded along the way.
- Carrying sufficient fuel and water for the journey.

- Evacuating early.

C. Managing Transportation Choke Points

Expedient evacuations can be severely limited by choke points. Examples of choke points include: tunnels, bridges, border crossings, toll booths, limited access routes, and islands & geographically isolated regions. Inoperative traffic lights can also produce choke points. It is the governments responsibility at all levels to deal with minimizing the impact of choke points.

Federal and national governments can relax border and custom checkpoints to neutralize these potential choke points. Governments should establish treaties in advance with their neighbors to facilitate emergency evacuation under the threat of an impact event.

In the event of an impending hurricane, two lane highways are converted into single direction roadways to facilitate evacuation. The same technique can apply to impact evacuations. A problem encountered in recent hurricanes evacuations traffic snarling to a standstill. It may be time critical to keep the transportation lanes open. Under these circumstances if a stalled vehicle or accidents should block the highway, individuals should be encouraged to take the initiative and push these vehicles off to one side of the roadway and keeps the traffic flowing. Planning should ensure that gas stations along the route are refueled, to ensure vehicles are not stranded because of a lack of fuel.

Another method to deal with choke points is establishing alternative evacuation routes or approaches.

Tunnels can present a unique choke point for evacuation plans. A number of accidents have occurred within tunnels in recent years producing deadly fires which shut down tunnels for days and weeks. This type of accident is a possibility during a major evacuation. Several alternative evacuation approaches exists. As an example, consider an evacuation of the citizens of Great Britain through the channel tunnel that connects it with France. This approach could equally apply to any large tunnel complex.

- Tunnel traffic can be restricted to buses only. A massive fleet of buses from all over England can be assembled to ferry individuals through the potential choke point, the channel tunnel. The buses would route from one major transportation node, for example a major train station, to another node on the other side of the tunnel. After dropping off a load of passengers, the bus would return to the initial node to pick up additional passengers.
- Another alternative could be to restrict truck traffic from the tunnel and then convert the two way tunnel traffic to one way traffic. This would double the traffic flow and reduce the potential for large accidents that could be difficult to clear.
- Another alternative could be to restrict all motorized traffic from the tunnels and use the tunnels for foot traffic only. Most healthy individuals could to make the 32-mile journey on foot in two days. The elderly, the infirm, and infants and very small children with their mothers can be transported by tunnel train to the other side. Buses and trains on the French side can be organized to pick up the people as they exited the tunnel and transport them to safer locations inland.

Alternative evacuation approaches requires a bit of out-of-the-box thinking. If Great Britain was threatened by an impending impact, the country might tap into their waterways as an evacuation route. Such an evacuation might operate like Dunkirk in reverse. The Battle of Dunkirk is not remembered for the number of people killed or captured. It was remembered for how many lives were saved, 340,000 men, an army. The evacuation came about because it became a "national imperative". Every Englishman that was able chipped in and executed the plan. Thousands of boats and ships, large and small, were drafted into service. The evacuation was executed under the most severe conditions of war under the threat of constant bombardment. But the result was that the lives of a third of a million men were saved in a matter of days.

Following the terrorist attack that destroyed the World Trade Center on September 11, 2001, New York City was evacuated. Part of the evacuation included a waterborne evacuation. Tugboats, ferries, fireboats, work boats and private pleasure boats came to the aid of its citizens and over the course of a day evacuated more than 300,000 people from Lower Manhattan.

D. Minimizing Damage

Large impact events may produce great damage to the infrastructure, making recovery operations extremely difficult and amplifying the level of the disaster. Most of the damage from the 1906 San Francisco earthquake came from secondary fires. The plan will define steps that can be taken in advance of the impact to minimize secondary damage. Examples are: lowering the water level in major reservoirs/dams, closing off and securing all underground oil/gas mains, taking nuclear reactors off line, and individuals shutting off gas lines to residences.

An impact has the potential of destroying nuclear power plants and releasing significant amounts of radiation into the environment. If the reactor pressure vessel is ruptured, the highest concentrations of radiation will be localized to the area within 5 miles of the reactor site. Most reactor pressure vessels are designed for blast wave overpressures exceeding 200-psi. As a result, the reactor vessel may survive the blast wave associated with the impact event. It would be important to take the reactor off-line prior to impact because in this state, reactors are more damage-resistant.[3]

Ground shock may shatter dams. The water in dam reservoirs within the zone of destruction should be lowered and emptied prior to an impact.

In Kuwait at the end of the first Iraq war, fleeing Iraqis ignited thousand of oil wells sending up clouds of black smoke plunging the country into darkness. A large impact can produce a similar effect, with the exception that there may be no one to put these fires out. A few oil wells are equipped with automatic master down-hole valves. These valves are designed to automatically shut off in the event of an earthquake. These master down-hole valves will also be triggered from the ground shock generated by large impacts. An impact has the potential of igniting oil and gas fires at the well heads of underground reservoirs and reserves, unless they are secured. These unchecked fires can produce poisonous gases; consume oxygen in an oxygen-depleted atmosphere; and lengthen the recovery time by blocking out sunlight. As a result, it is very important to close off and secure these master valves at the well head prior to impact.

Individuals whether they evacuate the site of the impending impact or seek shelter should take several steps to secure their home immediately before departure. Individuals should shut off the main gas line into their homes. This will minimize the potential for secondary fires and explosions after the impact. They should close the water mains into their homes. Individuals should turn off electricity by tripping the main circuit breaker. Individuals with outdoor tanks such as propane, winter fuel oil, petroleum, or farming chemical tanks should secure these tanks. In areas outside the 3-psi blast wave individuals should also cover their windows with plywood to protect it from the blast and should remove breakable item from shelves, cabinets and refrigerators and pack them in boxes on the floor. The impact ground shock can produce similar damage as earthquakes.

Air traffic should be curtailed immediately prior to an impact. Aircraft are vulnerable to the blast wave, thermal radiation, electromagnetic effects, loss of communication and the effect of impact debris.

E. Relocation of Key Industries & Assets

In June of 1941, Nazi Germany invaded the Soviet Union. Within days the Soviet Union was under a crippling ground and air attack from the Germans. One of the strategic decisions made by the Soviet Union at that time was to relocate 1,500 factories including the workers from the European USSR to the east. This move helped turn the tide of battle. If the United States under the threat of an impending asteroid or comet impact were to relocate key industries including personnel into protected zones, this move could have a profound impact in bringing us out of the Dark Ages by kick-starting civilization, with the restoration of the industrial age and the electronics age. This move might be executed using airlines and rail lines.

One aspect of the proposed impact disaster preparedness plan is for the government to identify in advance the key military and industrial assets which should be relocated in the event of this impact threat. The listing should be segmented by geographical areas. This approach would allow an orderly rollout based on the specific geological area threatened. This classified document should be updated at a minimum of once per decade. The list should not be so large as to become a cumbersome, unworkable tool.

V. Sheltering

The damage from a comet or asteroid impact is very similar to that seen in a comparable-sized nuclear explosion with the exception that an impact does not produce any radioactive fallout. Civil defense planning over the past 60 years has developed a significant body of knowledge on shelter construction against a nuclear threat including expedient shelter design. This shelter construction knowledge can be efficiently rolled-up into sheltering design against the blast and thermal effects from an impact event.

Evacuation may not always be an option. Geological and governmental barriers, point-of-impact uncertainty, limits on modes of transportation and limited time may preclude effective evacuation. Very large impactors (several miles in diameter) may rain destruction over the entire planet. Alternative options include sheltering in pre-existing man-made shelters or natural shelters or the construction of expedient blast shelter to survive the immediate effects of the impact. A 50-psi overpressure blast shelter can offer protection for approximately 98% of the area within the zone of destruction. Both the Soviet Union and the United States developed designs for construction of expedient blast shelters using commonly available material under short execution timeframe for protection against a nuclear threat. These designs should be updated, tested and the construction details incorporated into impact disaster preparedness plans.

This section will look at utilizing existing shelters, the construction of expedient shelters, the need for strategic shelters and shelter provisioning.

A. Existing Shelters (National Shelter Plan)

The damage from an asteroid or comet impact has been compared to that from a large nuclear weapon without the radiation fallout effect. This analogy is very useful in impact sheltering because the blast effects are quantifiable and shelter designs are testable.

Mines, tunnels and caves represent a large potential source of existing shelters that can shield against the blast effects of an asteroid/comet impact. Data from the Bureau of Mines was compiled into a National Underground Mines Inventory maintained by FEMA. This inventory identified approximately 35 million individual shelter spaces that could be created in U.S. mines.[4] Oak Ridge National Laboratory estimated that in the U.S. potentially 2 to 3 million spaces could be created in tunnels, 4 million spaces in caves, and a potential for up to 100 million spaces in mines (60-70 million in limestone mines, 20-30 million in salt mines, and 5 million spaces in gypsum and sandstone mines.)[5]

Using mines and caves as shelters has some drawbacks. For example, many salt mines are at depths of several hundred to a few thousand feet which is only accessible by small elevators with a capacity of holding only a few tens of people at a time. The infrastructure supporting these mines may be destroyed or disabled by the impact. As a result, exiting the mine after an impact may be more difficult task than entering the mine. Another hazard with old unused mines is the accumulation of deadly methane gas. Many deadly gases are heavier than air and will gravitate to the lower portions of caves and mines. Impacts can produce substantial ground shock that can cause cave-ins. These drawbacks should not preclude the use of mines and caves as shelter options but rather contingency planning is required to deal with these additional threats.

Several factors must be considered in applying this shelter option including access, ventilation, lighting and sewage disposal. Generally these are not insurmountable issues, but rather issues that must be dealt with in the planning and execution stages. One of the limiting factors in using caves, tunnels and mines was the requirement for a permanent lighting infrastructure. But recent advances in flashlight technology have produced a capacitor charged design eliminating the need for a battery. These flashlights (such as NightStar) are energized manually by shaking the unit which oscillates a rare earth magnet through a coil. The flashlight can be operated continuously for several years of useful life. This is well suited for meeting the lighting requirements within natural and man-made subsurface shelters. One approach in ventilating caves, tunnels and mines might be solved by directional fans easily fabricated from sheets of fabric and thin strips of wood.[6] For this method to work efficiently the structure requires an entrance and an exit in order to establish an air circulation pattern.

Sand bags can be used to seal off the railroad, subway and highway tunnel entrances from the blast wave. A minimal gap in the sandbags at the roof of the tunnel could allow ventilation.

Other types of existing underground shelters include atomic bomb shelters, storm shelters, underground houses and root cellars. Some of these types of shelters may perform very well against the blast effects of an asteroid/comet impact and the subsequent earthquakes. Atomic bomb blast shelters should be high on this list. Other types of underground shelters, such as root cellars may be weak and provide only minimal blast protection and may require significant reinforcing and strengthening. Fallout shelters should not be confused with blast shelters. Fallout shelters are designed to provide protection against radioactive fallout, not necessarily the blast effects of an atomic bomb detonation or an asteroid/comet impact.

Most of the damaging effects from a comet/asteroid impact will occur within the first 24 hours, after which individuals can leave the safety afforded by the shelters and begin rebuilding their lives.

In the event of an impending impact, the government should generate a streamlined method of offering shelter space to individuals that select this option.

In general, one of the quickest ways to disseminate information is through the internet. This plan recommends the development of a Shelter Registry Database, a web-based directory of shelter locations. Rather than a single national database the data shall be broken down into multiple website, each covering a specific geographical region. It will be keyed off of postal zip codes. This is to minimize computer system crashes associated with heavy internet traffic load. It will list shelter locations for a specific postal zip code and immediate adjacent zip codes.

The website information will include: shelter name, type of shelter, location of shelter access point and general directions to shelter, approximate number of individuals shelter will house, overpressure rating in psi for shelter, and a list of supplies/equipment (for example ropes, ladders for access, flashlights, 5-gallon plastic buckets for sanitation, water & food).

This website will contain sensitive information. As a result the website will be in inactive status until a threat is deemed probable and immediate. At which point, the matrix of websites will be activated and the general public will be instructed on the availability and use of the information. The civil defense information in the website is valuable for several threats including asteroid/comet impacts, nuclear war and high energy nuclear radiation burst from nearby supernovae.

Shelter inventory shall cover only public shelters and mines, caves and tunnels. Even though the land containing caves, mines, subway systems etc. shall be owned by individuals, companies, municipalities etc., the federal government should apply emergency powers to place these shelters under the control of the federal government during the time of the emergency and make them available to its citizens. Ownership of these shelters will revert back to their original owners once the threat is past.

Individuals shall make decision on which shelters to use and shall not be restricted to only shelters within their postal zip codes. But individuals must recognize occupancy limits on shelters. Entry to shelters shall be on a first come, first serve basis. Shelter space shall not be reserved.

B. Expedient Shelters

Expedient shelters are shelters that can be constructed by untrained citizens in 48 hours or less, guided solely by field-tested, written instructions and using only widely available materials and tools. These are just-in-time shelters, shelters that will be constructed after an immediate threat is identified. The concept is analogous to just-in-time manufacturing. United States and Soviet expedient shelter designs include shored trench shelters, door covered trench shelters and small pole covered trench shelters.[5,6] Some of these designs have been verified by testing to withstand overpressures in excess of 100-psi. As a frame of reference, winds from a blast wave of 3-psi overpressure are sufficient to kill a person caught out in the open. A typical residence will collapse by an overpressure of 5-psi. A blast wave of 10-psi to 12-psi will convert most large office buildings into rubble. At 20-psi, reinforced concrete structures are leveled.

The primary goal of an expedient blast shelter is to survive the immediate effects of the impact. A 50-psi blast shelter can protect individuals within approximately 98% of the area within the zone of destruction. In order to achieve the 50-psi blast protection goal, the shelter is designed as:

- An underground shelter.
- Earth arching construction.
- Shored sidewalls.
- Covered entrance.

Earth arching increases the load-carrying capability of buried structures.[5] It allows the soil to redistribute the blast load evenly into "arches" which transfers the load away from the structure. In order for earth arching to occur, the following conditions must be met:

- The structure must be above the water table.
- The structure cannot be built in water saturated soil.
- The structure must be buried in granular soil or the site must be backfilled with granular soil.
- The depth of earth covering above the structure must be at least one-half of the minimum span of the structure. (That is why many of these designs take the form of a trench)
- The structure must be flexible enough to yield under the applied load.

Expedient shelter design should also incorporate shored sidewalls. During the 1950-1970, the U.S. government conducted a number of blast tests on various shelter designs. In October 1976, the DICE THROW tests exposed a number of expedient shelters to the blast from a 600-ton ammonium nitrate-fuel oil explosion. One of the findings from this test program was that unshored covered trenches collapsed from ground motion at relatively low overpressures.[5]

Impact disaster preparedness planning should rely upon expedient shelters as a cornerstone option. The government's role is:

- Develop a wide mix of expedient shelter designs.
- Validate through testing individual designs.
- Provide via the internet detailed design packages.

The individual's/families' role is:

- Select the most appropriate design.
- Construct the shelter.

Although several designs for expedient shelters exist, it is important to expand the range of design options. Flexibility in design will be needed due to constraints on and access to building materials. For example, some expedient shelter designs proposed utilizing existing readily available interior house doors. But today's hollow core doors are not the same as solid wooden doors of the 1950's, when the original civil defense plans were developed. Also several other designs rely upon cutting down 4-inch diameter trees to make poles. In many locations availability of small trees will become an issue. On the other side, one of the best building materials available today is plywood (a very strong yet flexible building material). Plywood is not incorporated into any of the current expedient shelter designs.

This plan recommends the government sponsor an academic design challenge competition for expedient shelter design. The approach would be analogous to an automotive solar car competition where various college engineering teams design, assemble and test solar powered cars in a competitive race. The winning shelter designs would be constructed, tested and evaluated under various blast pressures to gauge the survivability of each design. This approach would produce a diverse set of designs that would maximize flexibility. The competitive design area should focus on:

- The limits of various below-ground shelter designs to survive blast overpressures.
- The limits of various shelter entrances and closures designs to survive blast overpressures.
- The limits of various air exchange system designs to survive blast overpressures.
- The limits of various above-ground shelter designs to survive blast overpressures.

From these tested designs, the government can develop a suite of shelter designs; each design package will include design drawings, a list of required building materials, a list of tools needed and general construction procedures. The mix of designs packages should be internet web-based and easily printable. Multiple servers should provide this information to preclude bandwidth problems. The information should be permanently available on-line. This will allow individuals to become acquainted with the designs prior to any impact threat materializing.

C. Strategic Shelter

A large impact event is very capable of producing an extinction boundary. An impact disaster preparedness plan should expand its role beyond ensuring the survival of its citizens to also include the survivability of its knowledge, the fabric of its civilization, and its ecosystem (plants/animals/birds/marine life). The Federal Government has an inherent role in the construction and maintenance of strategic shelters to protect these valuable elements. Mankind can make the greatest impact on the survival of life-forms on this planet by creating a Noah's Ark in the chaos of an extinction boundary. The need for strategic shelters is not limited to impact events but also encompasses a variety of threats including major species epidemics, full scale nuclear war, nearby supernova events and other great natural or man-made cataclysms.

Currently there are approximately 1,400 national seed banks located around the world. Norway has begun the construction of a Global Seed Vault in Svalbark, Norway that is capable of protecting 3 million crop seeds. The advantage of this permafrost location is the natural dry cool environment that can extend seed life to thousands of years. The U.S. government should participate in this program and also construct two seed vaults on Federal land as permanent strategic shelters of its own. One should be constructed in a permafrost region of Alaska and the other high up in the Rocky Mountains in the continental United States.

The U.S. government currently supports a genetic preservation program for endangered breeds of livestock. The U.S. Department of Agriculture runs the National Animal Germplasm Program. The Swiss Village Foundation (SVF) in Newport, Rhode Island is another collection that focuses on endangered breeds. These efforts should be integrated into impact disaster preparedness planning.

The government should also construct a permanent specialized strategic shelter to ensure survivability of the global ecosystems. This strategic shelter would provide the infrastructure to support relocation and survivability of the animals, birds and marine life. In the event of an impending large impact, selected species from farms, zoos & aquariums, wild-life parks and preserves, woodlands, deserts, rivers and oceans, could be expeditiously relocated to this shelter complex. The wide belt of mountains and the high plateaus along the western United States will make ideal "safe harbor" areas. A large portion of the land areas comprising the western mountains and plateaus are controlled by the Federal government. I propose the federal government assume the responsibility of the construction and maintenance of this strategic shelter complex. Since the western areas can be arid, dry and almost desert like, water becomes an important issue. I propose this strategic shelter be constructed along the great western rivers, either the Colorado River or the Snake River.

The government should also construct a permanent specialized strategic shelter as global repository of knowledge. This repository should be co-located with the strategic shelter protecting the global ecosystems and should be constructed to withstand a 50-psi blast wave. The repository should shelter and store the vast wealth of scientific, medical, engineering knowledge and literature in electronic form. The shelter should provide infrastructure for an expanded growth mission. In the event of an impending large impact, books and other historical documents could be relocated from the major world libraries to this site to insure their continued survivability. The shelter could further support another mission by providing a secured backup site for key financial electronic data and other resources such as patent records.

VI. Post Impact Recovery

The majority of the damage from an impact will occur within the first 24 hours after the time of impact. The damage from thermal radiation and ground shock will be almost immediate. The damage from the atmospheric blast wave and tsunami will generally occur within 12 hours after the impact (a large impact, ~ 1-psi blast radius). After this time, individuals within the zone of destruction will begin to leave their underground shelters and enter into a disaster recovery period. Pre-impact planning is required at both the governmental and individual/family level to maximize survival during the disaster recovery stage.

A large impact can cause significant damage to the infrastructure that we generally take for granted (electricity, water, sanitation, petroleum, food, transportation and communications). The loss of this infrastructure can severely stress post impact recovery efforts. Individuals and families should take these factors into account in the planning phase. Since transportation could be significantly affected by a large impact, it might be advisable for individuals in cities to relocate to rural settings before the impact. This is especially true for individuals who have family ties in the countryside. Relocating to the countryside will place individuals and families nearer the stored food supplies.

Disruptions to the farming community and transportation community by a large impact event can produce malnutrition and starvation. This in turn can increase the susceptibility to disease and produce epidemics and plagues. In general, most of the deaths from a large impact may be driven primarily through starvation and disease rather than by the direct damage effects caused by the impact.

After a large impact, the surface of the earth will be covered by a layer of ash and soot. This layer will contain heavy metals and other toxins from the fallout of the impact event. These heavy metals can be absorbed by plant life and enter the food chain. This layer should be scraped away from the field's topsoil prior to the initial planting of seeds. Since surviving animal life may graze on contaminated lands, eating meat may be hazardous because it will be contaminated with heavy metals passed up the food chain.

A. Provisioning

For those individuals that select to remain in the zone of destruction, the size of the impactor should determine the amount of effort needed to prepare for surviving until help arrives. For small impacts, help might be available in minutes and hours. For very large impacts, help might come in years or not at all. The impact disaster preparedness plan should address preparation for surviving without the basic elements (clean water, food, sanitation, electricity etc.) Factors for individuals to consider include: manual filtration systems for purifying the water, home made sanitation systems for minimizing contamination to drinking water supplies, seeds for planting, grain storage and processing for food, and general survival advice geared to impact devastation. The government should develop and freely make available this information via the web.

One of the basic human survival needs is water. When the Katrina hurricane struck New Orleans, there was a severe shortage of drinking water. If the drinking water was not trucked in, many individuals would have perished or likely become very sick. In a large impact event where the basic infrastructure is destroyed, a means to trunk in drinking water might no longer exist. But vast quantities of water were readily available all over New Orleans, only the water was highly polluted. Manual filtration systems are available that could handle even this level of polluted water. The government can provide guidance on the construction of water purification systems (such as slow sand filtrations systems,[†] gravity feed water filtration systems,[‡] and the availability of existing equipments (such as ceramic water filters) and the limits of their effectiveness.

Another basic human survival need is food. Obtaining a long-term food supply is one of the first challenges for the individuals. We are accustomed to obtaining food from grocery stores. These assets are insufficient and will be quickly exhausted. The only viable long term food source capable of carrying us through a large impact event is raw grains, corn, soybeans.

Most of the world lives on grass seeds; wheat, oats, rice, millet and other cereals are grasses.[7] In the United States, corn is a natural choice for food storage because of it's abundance. The United States produces vast quantities of food. In the 2005/2006 trade year, the U. S. farmers produced 63.2 million tons of wheat, 7.8 million

[†] Water for the World, "Constructing a Slow Sand Filter", Technical Note RWS.3.C.3, URL: http://www.lifewater.org/resources/rws3/rws3c3.pdf [cited 28 November 2006].
[‡] Marusek, J.A., "Gravity Feed Water Treatment System", URL: http://personals.galaxyinternet.net/tunga/I38.htm [cited 28 November 2006]

tons of rice and 329.3 million tons of coarse grains (corn, barley, sorghum, oats, rye, millet and mixed grains). This production equals approximately 400 million tons.[8] The majority of grain produced in the United States is in the form of corn. Most of this grain is currently used as livestock feed.

The minimum daily requirement for food is 2,100 calories per person.[9] Grain meal provides between 1200-1700 calories per pound. One ton of grain is required to supply the needs of one person for three years. Sufficient grain exists in the U.S. at any given time to support its population for approximately 3 years provided the grain can be protected from the impact damage including the blast wave, rain and debris following the impact.

Individual and families may decide to purchase and store grain supplies prior to an impact event. Grains in this nation are stored by farmers and by organizations such as farm cooperatives, and Feed & Grain stores. The quickest method to obtain a large quantity of grain is for individuals to drive up to a farm coop and have them load bags of grain onto the back of their pick-up truck. Feed and Grain stores are also able to handle large shipments which they can deliver to any destination in bulk form. Whole corn kernels are recommended rather than cracked corn to extend the shelf life and to facilitate the cleaning the corn prior to processing.

B. Other Considerations

There are several factors individuals should consider in preparation for surviving this type of cataclysm.

- Water: Water treatment methods.[§]
- Food Preparation: Grains (especially corn) can be very difficult to process. Manually operated grain mills are extremely useful in this type of emergency.
- Sanitation: Sanitation systems.[**]
- Cooking: The blast effects from a large impact can lay to waste vast forest. These trees could be converted into firewood to support cooking needs provided individuals have axes, chainsaws etc. for processing the wood and outdoor cooking gear such as cast iron pots.
- Lighting: A large impact can destroy the infrastructure including electrical power generation and distribution. Lighting can be augmented in a long term emergency with magnetic powered LED flashlights which can operate without batteries.
- Post Impact Shelters: Although tents might offer a temporary shelter after this type of cataclysm, a more permanent shelter will be required in the long-term. The materials used in the construction of expedient shelters could be recycled into the construction of above ground shelters after the impact event. The material from destroyed homes and buildings could be recycled into construction. In general, the above ground shelter should be simple, water-tight and insulated. Pre-positioned underground storage of some basic building material (plywood, fiberglass insulation and EDPM rubber roofing) might go a long ways towards quickly reconstituting a permanent no-frills above-ground shelter.
- Communications: Technology has increased the flexibility of communications. Current communications relies on an infrastructure grid that may be destroyed during a medium to large impact event. Therefore at the individual/community level, my recommendation is to return to basics, a ham radio license and HF mobile transceiver. The unit can be powered by a car battery and the communications can reach around the world without a repeater.
- Medical/Dental: Injury and disease may arise after an impact and current medical expertise, facilities and supplies may be unavailable. Expert text dealing with medical/dental problems in a low tech environment would be helpful to survivors. “Where There is No Doctor” is a comprehensive emergency medical guide.[10] Included in this book is a description of material needed for a home medicine kit (pp. 334-335) and a small community medical kit (pp. 336-337). This medical kit might be expanded to capture recent DoD driven advances in medical treatment such as Quick Clot.[11] “Where There is No Dentist” is a fairly comprehensive emergency dental guide.[12]

The government should offer expert advice. This advice should be available on-line in a web-based format.

VII. Conclusion

Disaster preparedness planning is a very cost effective element of an overall mitigation plan. This planning doesn’t require the commitment of vast funding. This planning can provide great return-on-investment in terms of

[§] Lifewater International, “Water Treatment”, RWS.3, URL: http://www.lifewater.org/resources/water_treatment.html#WT [cited 28 November 2006].

[**] Lifewater International, “Sanitation: Simple Excreta and Washwater Disposal”, SAN.1, URL: http://www.lifewater.org/resources/sanitation.html#SAN [cited 28 November 2006].

lives saved, averting the destruction of key industries & assets, preventing secondary damage effects, reducing chaos and speeding post-impact recovery should this specific threat materialize.

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