Planetary Defense: Progress And Enormous Challenges

Benjamin Deniston reports from the Planetary Defense Conference in Flagstaff, Arizona, sponsored by the International Academy of Astronautics.[1]

April 26—The Third Planetary Defense Conference was held on April 14-19, bringing together experts from a wide range of fields to discuss how to defend the Earth from the threats inherent in our Solar System. While the Chelyabinsk asteroid impact over Russia on Feb. 15 alerted the general public to the importance of planetary defense, the conference showed that a dedicated and growing community has been focusing on this issue for the past two decades. There were hundreds of participants, including from NASA, the European Space Agency (ESA), Russia's Roscosmos, Germany's DLR, and other space agencies; Lawrence Livermore and Los Alamos National Laboratories, the Russian Academy of Sciences, the United Nations, various aerospace corporations, emergency response organizations, and universities from around the world.

The conference banner. Flagstaff is 43 miles from the Barrington Crater (pictured), formed by the impact of a of an asteroid fragment 50,000 years ago.

The conference was packed with presentations on all aspects of the subject, from detecting threatening asteroids, to disaster response measures if one were to hit Earth; means of deflecting an asteroid; and studying its composition and structure for clues about the early formation of the Solar System.

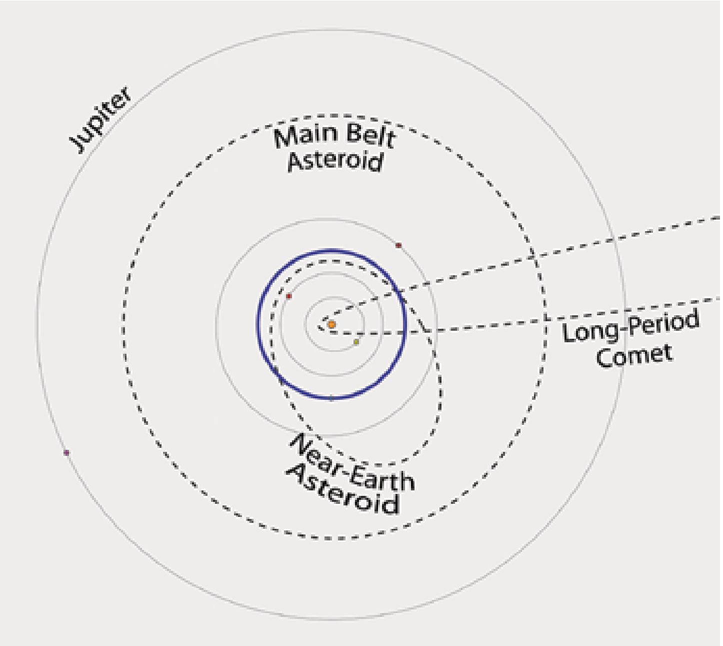
A special session began the conference, "Preliminary Look at the Chelyabinsk Event," which was open to the public, due to the extraordinary interest in the subject. Presentations included a report on a two-week field study in the Chelyabinsk Region by a team of scientists from Russian institutions and the SETI Institute in California.

Recent History and Context of Planetary Defense

Unfortunately, despite decades of work on the subject, many of the key outstanding issues posed today are the same ones that were identified when government efforts related to planetary defense started to get moving. The lack of fundamental progress over the

1. A longer version of this article will appear in *21st Century Science & Technology* magazine.

FIGURE 1
Comparison of a near-Earth Asteroid Orbit and Long Period Comet Orbit



Near-Earth asteroids have different orbits than the "main belt" asteroids, which remain between Jupiter and Mars. NEOs can cross the Earth's orbit on a regular basis, with the potential for an collision.

past two decades is not the fault of the scientists working in this area, but expresses the larger trend of national and international economic stagnation and regression since the assassination of President John F. Kennedy.

The United States has abandoned the general practice of science-driver programs, of which Kennedy's Apollo Project was a prime example. Such programs create technological revolutions that fundamentally change mankind's relationship to the universe, inspire nations, and shift the economy as a whole onto a trajectory that optimizes creative discoveries that benefit the general welfare. Absent that approach, the progress in planetary defense research has been largely incremental.

By the early 1990s, there was a growing recognition of the threat from space objects, and the most immediate task was to see if any of the largest near-Earth objects (NEOs),[2] those which could threaten all civilization, were on an impact course. According to an individual involved in this initial effort, to speed up the search, certain non-public defense assets were allocated. It turned out that ground-based assets already designed to look for small man-made objects orbiting the Earth could do a decent job of finding much larger natural objects much farther from the Earth. It was determined that none of the largest asteroids posed a threat over the next few decades (an assessment that NASA was able to publicly provide a few years ago). This left two areas of concern: small to medium-sized asteroids, and long-period comets.

Small to medium-sized asteroids can pack enough energy to level a city, a nation, or even a continent. There are many more of them than there are large NEOs, and they would be hard to deflect because their small size makes them difficult targets.

Long-period comets take the challenge to a new level (**Figure 1**). They are generally larger than asteroids, can travel significantly faster, and can have unpredictable trajectories. Furthermore, they reside in the outermost regions of the Solar System (much, much farther away than asteroids), where they are presently impossible to see with existing systems, and can only be detected when they are coming close to Earth (when it might be too late to act if one were on an impact course).

Detection: Finding Asteroids Before They Find Us[3]

Near-Earth object discovery programs were the subject of the second session of the conference, "Discovering NEOs—The State of the Art."

There are millions of asteroids in the inner Solar System, many of which cross the Earth's orbit on a regular basis. The exact number is unknown. For those of the size of the one that exploded over Chelyabinsk (15-20 meters in diameter), it was estimated at the conference that there are on the order of 10 million asteroids populating the inner Solar System. Only about 1,000 are presently known! *Before the Earth can be de-*

2. Near-Earth objects, or NEOs, are asteroids and comets that orbit in the inner Solar System. Sometimes the term near-Earth asteroid is used as well.

3. To borrow from the title of Don Yeomans' book, *Near-Earth Objects: Finding Them Before They Find Us* (Princeton University Press, 2012).

TABLE 1

The Population of Near-Earth Objects

Size Range (Diameter in Meters)	Approx. Estimated Population	Approx. Number Found	Approx. Percentage Found	Range of Impact Effects	
30 and less	12 Million	1200	~0.01%	AIRBURST	Could burn up in the atmosphere unnoticed, or cause structural damage and causalities on a local scale significantly worse than in Chelyabinsk.
30-100	500 Thousand	2000		CITY-KILLER	Could completely destroy a region from the size of a city to a medium-sized nation.
100-300	21000	2100	~10%	NATION-KILLER	Could devastate a region from the size a medium-sized nation to an entire continent. Ocean impacts could cause very wide-spread tsunami devastation.
300-1,000	4800	2400	~50%	CONTINENT-KILLER	A territory ranging from the size of a content to the entire globe.
1000 and greater	900	860	~95%	CIVILIZATION THREATENING	The entire Earth would be affected by the impact effects, including an "impact winter."

The population estimations are rounded from NASA's 2012 estimates. The impact effects express the consensus of a number of sources; note that there are many details which would play into any actual impact situation.

fended from an asteroid threat, that threat must be identified—with enough warning time to act.

However, the Chelyabinsk impactor was relatively small. **Table 1** shows the range of NEO sizes, with a corresponding range of intensity of the impact effects: from those that burn up high in the atmosphere, never causing any noticeable effect on the ground; to those that would impact with so much energy that enough material would be lofted into the upper atmosphere that the Sun would be blocked, the climate would be altered, and photosynthetic life worldwide would be devastated—including the food crops which sustain human civilization.

Currently, the majority of the known near-Earth objects have been discovered by ground-based telescopic survey programs funded by NASA. In 1994, Congress directed NASA to identify and catalog 90% of the large asteroids (1 km and larger) within 10 years. With steady progress on meeting the 1 km goal, in 2005 Congress directed NASA to find 90% of the asteroids down to 140 meters by 2020. With current funding levels, this goal will not be met.

Ground-Based Survey Programs:

Don Yeomans, the Supervisor for the Solar System Dynamics Group at NASA's Jet Propulsion Lab (JPL) and Manager of the Near-Earth Object Program Office, gave an overview of the current ground-based surveys dedicated to search for near-Earth objects. These programs, sometimes loosely referred to as part of the SpaceGuard program, survey large sections of the sky each night, imaging the same location multiple times to then compare the images to look for moving objects. Three observation programs have contributed to the bulk of that effort to date:

Lincoln Near-Earth Asteroid Research (LINEAR): Using two telescopes in Socorro, N.M., this program led in the NEO discovery effort from 1998 to 2004. The discovery rate has since fallen off, but they are still operating, and are now helping to bring a next-generation survey telescope, DARPA's Space Surveillance Telescope, into the asteroid detection effort.

Catalina Sky Survey: Three telescopes, two just outside of Tucson, Ariz., and the third in Siding Spring Observatory, Australia. Overtaking LINEAR in 2005, Catalina has contributed the most discoveries of near-Earth objects so far.

Panoramic Survey Telescope and Rapid Response System (Pan-STARRS): Currently one new telescope in Hawaii, and a second under construction. This newest and most advanced asteroid search system is expected to continue to expand the number of discovered asteroids over the coming years, perhaps overtaking Catalina.

While NASA is leading the efforts, other nations are contributing or are planning to contribute to the effort:

La Sagra Sky Survey (LSSS): The European Space Agency's Space Situational Awareness (SSA) program, is supporting the LSSS, which is operating in Granada, Spain, in their search for near-Earth objects. The head of the near-Earth asteroid division of the SSA, Detlef Koschny, presented the status of their program.

AZT-33VM: The Russian Academy of Sciences is developing a new ground-based telescope to search for asteroids. Located in Irkutsk, Russia, AZT-33VM is expected to begin operations by mid-2014, and to be fully operational 1-2 years after that. This was presented by the head of the Russian Academy of Sciences Institute of Astronomy, Boris Shustov.

These ground-based observation programs, along with a few others, have been most successful in finding larger asteroids. They can only detect small or medium-sized asteroids (such as city- or nation-killers) when they come close to the Earth. Because these searches cannot survey the entire sky every night, smaller or medium-sized asteroids can often sneak up, coming very close, or even passing by, before they are detected—if they are seen at all. This means they could impact at any moment with little or no warning, as the Chelyabinsk asteroid did.

Searches that do not look as deep into space, but survey the entire sky more rapidly, are now being developed. These would not provide enough advanced warning to stop an impact, but would ensure that there are at least no surprises:

Asteroid Terrestrial-impact Last Alert System (ATLAS): In an attempt to get at least a few days or weeks of warning time, NASA is beginning to fund the development of the ATLAS program. When operational in 2015-16, this system will survey the entire night sky visible from Hawaii twice each night, to detect any incoming asteroids. This will be done by trading off depth (distance) of search for speed of survey, in order to see the entire visible nighttime sky. As presented by the head of the ATLAS project, Dr. John Tonry of the University of Hawaii, this is intended to provide warning times of at least a few days for city-killing asteroids, and up to a few weeks for nation-killing asteroids: not enough time to stop impact, but, in theory, enough time to try to evacuate or otherwise prepare for the consequences.

Fly-Eye Telescope Concept: The ESA's Space Situational Awareness program is also trying to develop a similar survey system, which would be able to detect asteroids down to a size of 40 meters across, providing at least three weeks' warning time before impact. The system calls for 4-6 telescopes stationed in different locations, although they only have funding to build one prototype. Program Head Koschny said that within four years, he hopes to have some results from the prototype.

While these ground-based programs continue to operate, and new programs are coming online, there are fundamental limits to their capabilities. If we are to discover threatening asteroids with enough warning time to be able to change their orbit or to destroy them so they don't hit the Earth, then much longer warning times will be needed, and the total number of known and tracked near-Earth objects must rise from its present level of ~10,000, towards many hundreds of thousands, or even millions.

This will require some qualitative changes to the approach.

Space-Based Observation

Simply extrapolating the current discovery rate indicates that it would take another 180 years to get to around 1 million near-Earth objects.[4] Not only is that far too long to wait, but it could not actually happen by extending the current types of observation programs.

During an overview of NASA's activities in detecting near-Earth objects, NASA headquarters program executive for the near-Earth object program office, Lindley Johnson, said the discovery rate has probably already begun to level off. He explained that the limits are being reached for what can be done with existing technology.

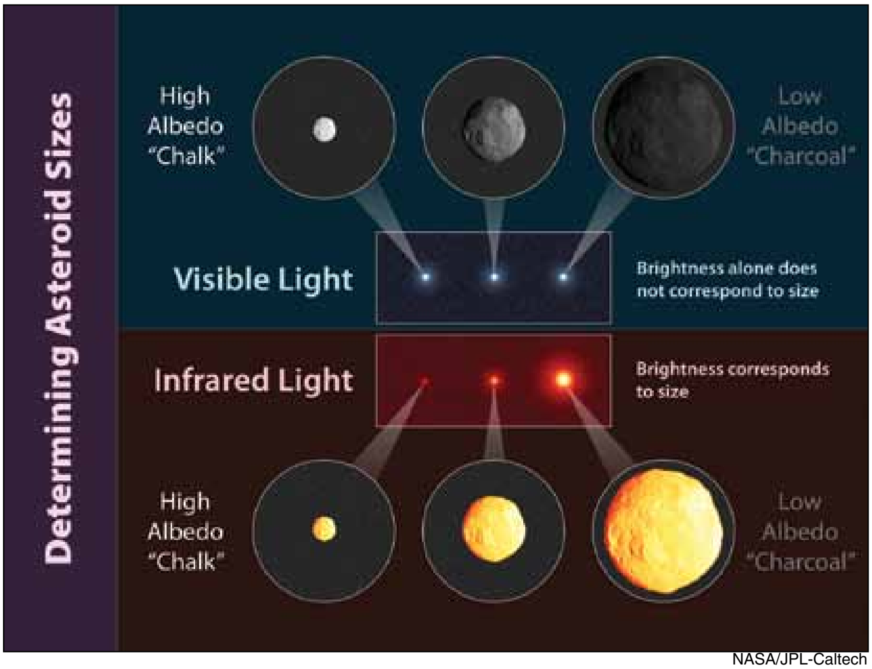
Not only are the smaller asteroids much more difficult to see, but searching from the Earth's surface has inherent limitations:

- Viewing can only occur at night (the half of the sky facing away from the Sun);
- Weather can pose problems;
- The atmosphere causes distortions, and blocks certain wavelengths of light from reaching the Earth's surface;
- Many asteroids have orbits that ensure they won't be visible from the Earth for years.

To address these issues, asteroid-detection systems must move off the Earth, and into space. Observation systems in space, either in Earth orbit, or stationed at

4. In 2012 there were almost 1,000 new near-Earth objects discovered, and the yearly number of asteroids discovered has increased by ~50 a year (averaged over the past 17 years of observation). A discovery rate of 1,000 per year, increasing at 50 per year, would bring the current level of 10,000 to 1,000,000 in about 180 years. However, this mathematical extrapolation is not a realistic scenario for the reasons discussed above.

FIGURE 2



NASA/JPL-Caltech

This chart illustrates how infrared is used to more accurately determine an asteroid's size. As the top of the chart shows, three asteroids of different sizes can look similar when viewed in visible light. This is because visible light from the Sun reflects off the surface of the rocks. The more reflective, or shiny, the object is (a feature called albedo), the more light it will reflect. Darker objects reflect little sunlight, so to a telescope from millions of miles away, a large dark asteroid can appear the same as a small, light one. In other words, the brightness of an asteroid viewed in visible light is the result of both its albedo and size. The bottom half of the chart illustrates what an infrared telescope would see when viewing the same three asteroids. Because infrared detectors sense the heat of an object, which is more directly related to its size, the larger rock appears brighter. In this case, the brightness of the object is not strongly affected by its albedo, or how bright or dark its surface is. When visible and infrared measurements are combined, the albedos of asteroids can be more accurately calculated.

other locations in the Solar System, have the potential to overcome each of these limitations. One system has successfully demonstrated the initial technology, and others have been proposed:

Near-Earth Object Wide-field Infrared Survey Explorer (NEO-WISE): Launched in December 2009, NASA's WISE space telescope imaged the entire sky in infrared wavelengths (which do not reach the Earth's surface because of the atmosphere) until the infrared sensors used all their coolant supplies. When the primary mission ended, NASA's Planetary Division funded an extension of the program, called NEO-WISE, to use the WISE telescope to search for near-Earth objects (including examining the existing WISE observation data for NEOs). Since WISE was not initially designed to look for asteroids, NEO-WISE did not find a huge number of new near-Earth objects (though it did find 135), but it was able to demonstrate the potential benefits of infrared systems. Since it also imaged many already known NEOs, the data from the NEO-WISE mission provided for improved estimations of their sizes, and new estimates of the population (**Figure 2**).

Near-Earth Object Camera (NEOCam): Proposed to NASA in 2005, and again in 2010, NEOCam would be an infrared space telescope that would orbit the Earth searching for near-Earth objects. The infrared detector would be passively cooled (meaning it would not require coolant), and in 2010, the team was given some initial funding to make prototype infrared detectors that would be optimized to search for near-Earth objects. As Amy Mainzer, principal investigator of the NEO-WISE program and the NEOCam proposal, presented at the conference, the science team expects that NEOCam would find two-thirds of the near-Earth objects down to a size of 140 meters, as well as a significant number of smaller ones. One of the benefits of being outside the Earth's atmosphere is the ability to see closer to the Sun, into regions blocked from the Earth, she explained.

Russian Academy of Sciences (RAS) Proposal: Russia is considering a space telescope system that would look for near-Earth objects in visible wavelengths. At the conference poster session, one RAS concept was for either one or two optical space telescopes that would image the entire visible sky once a day from Earth orbit. The general goal would be to find asteroids down to 100 meters in diameter, no later than 15-25 days before possible impact. An exact design has not yet been decided upon.

Sentinel Mission: In 2012, the non-profit B612 Foundation announced plans to raise private donations to design, build, and launch an infrared space telescope to search for NEOs from a Venus-like orbit. If they can meet their fundraising goals, the Sentinel Space Telescope would launch in 2018, and its designers claim that it would discover more than 90% of the asteroids down to 140 meters over 6.5 years of operation. They would expect to find 20,000 NEOs within the first two months of operation (twice the presently known population, after decades of searches). B612 CEO Ed Lu presented an update on their work at the conference.

These four proposed space missions are currently in some stage of design or development, and there have been other variations proposed. With millions of undiscovered near-Earth objects orbiting the inner Solar System, programs like these are absolutely needed, and ideally, a combination of such programs (each with its own benefits and drawbacks), would provide the beginnings of the qualitative change required in the search effort.

Unfortunately, there was no serious discussion at the conference of developing systems to ensure the early detection of long-period comets, which are much more difficult to detect early enough to stop an impact, as they spend the vast majority of their time much farther away. Although less frequent than asteroids in their approach to Earth, it would take only one long-period comet to end human civilization. With current observation systems, there would be at most a few years' warning (likely not long enough to design, build, launch, and execute a successful deflection mission with today's capabilities).

As a minimal effort, and part of a layered defense, systems like NASA's ATLAS and the ESA's Fly-Eye concept would give a few days or weeks' warning time before an impact, enough for some emergency preparations, but not enough to prevent the impact. Space-based surveys are needed to add another layer, to discover entire populations of NEOs down to certain sizes, allowing specialists to calculate their positions decades into the future, hopefully giving years of warning time before an impact. With that amount of time, it becomes possible to take active defense measures.

Planetary Defense

The fourth conference session was dedicated to techniques and missions for stopping an asteroid from impacting the Earth, with nearly 30 presentations on the subject.

Asteroid and comet impacts with the Earth could be prevented, given the right technologies. The first consideration is *time*. If the impact can be predicted many decades in advance, the action required could be as simple as slowing the asteroid down by less than one centimeter per second. Even this small change, if effected many years before Earth impact, could add up to enough of a change in position to avoid impact. If there is less warning time, it may be necessary to use thermonuclear explosives to blast the object into many pieces.

The more warning time given, the less effort it takes to deflect an incoming asteroid or comet. However, there are uncertainties that come with longer warning times. The farther into the future a trajectory is projected, the greater the range of error. This depends upon how precisely the orbit of the asteroid or comet is known, but also upon certain non-gravitational factors, such as solar radiation, which can have a significant influence on the position of small and-medium sized objects over decades.

While a number of different deflection systems have been theorized and proposed, only a few are considered feasible in the near term. The National Research Council published a comprehensive report on planetary defense in 2010, which concluded that thermonuclear explosives and "kinetic impacts" (running a spacecraft into the asteroid or comet) are the only options available with existing technologies.[5]

It must be emphasized that these are the same fundamental options that were available in the early 1990s, and the more advanced capabilities that were being discussed back then have not been implemented (such as nuclear rockets, electric propulsion, lasers, and D-He-3 fusion drivers).

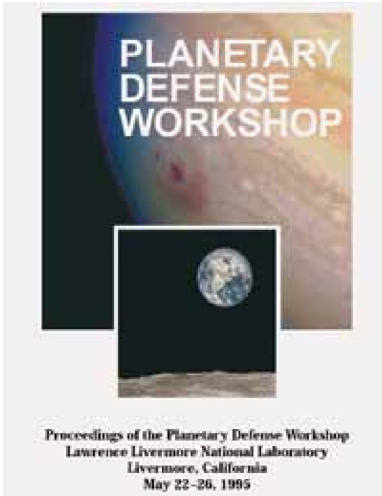
However, even talking about the "available options" is misleading. Although the technologies exist in principle, they have never been tested. There have been extensive studies, but only on paper and in computers, and certain fundamental questions cannot be answered until physical tests are conducted. For example, how exactly will the asteroid respond to an impact or an explosion? Will an impact kick off excess material, increasing the deflection effect, or will the

5. "Defending Planet Earth, Near-Earth Object Surveys and Hazard Mitigation Strategies," by the National Research Council's Committee to Review Near-Earth-Object Surveys and Hazard Mitigation Strategies, 2010.

impact be totally absorbed by the body? These are some of the outstanding questions that were discussed at the Flagstaff conference.

The key programs are summarized here:

Asteroid Impact Deflection Assessment (AIDA): Andrew Cheng of Johns Hopkins University Applied Physics Laboratory presented the ESA's AIDA mission, a kinetic impact test scheduled for launch in 2019, and impact in 2022. The mission will include two spacecraft, an impactor (DART), built at Johns Hopkins, and a second spacecraft to monitor the effects of the impact (AIM), built by ESA. DART will crash into the smaller asteroid of a binary asteroid system, 65803 Didymos, and AIM will be able to observe from a safe distance, to determine the efficiency of the impact by measuring the resulting change of the smaller asteroid's orbit around the larger asteroid (an effect that is easier to measure than the change in the orbit of an asteroid around the Sun). Vital information about the response of an asteroid to kinetic impacts will be gained, including impact effects such as crater size, material ejected, seismic effects, and shock waves.



Impactor for Surface and Interior Science (ISIS): This is a proposed asteroid impact mission that would work in conjunction with the existing OSIRIS-REx sample return mission. OSIRIS-REx is a scientific mission scheduled to launch in 2016, rendezvous with asteroid 1999 RQ36, collect a sample, and return it to Earth in 2023. Presented by Steve Chesley of JPL, the ISIS proposal is to launch a second spacecraft, which would impact asteroid 1999 RQ36 after OSIRIS-REx collected its sample, but before it leaves the asteroid. OSIRIS-REx would then be able to observe the impact and the subsequent effects, providing valuable information about kinetic impact effects. They are seeking NASA funding for the mission.

Iowa State Asteroid Deflection Research Center (ADRC): Bong Wie started this program in 2008. Currently Professor Wie and his team have a grant from the NASA Innovative Advanced Concepts (NIAC) program to design a system that can deliver a thermonuclear explosive device to disrupt a small to medium-sized asteroid when there is short warning time before impact, a system called the Hypervelocity Asteroid Intercept Vehicle (HAIV). Short warning time translates into the requirement for very fast intercept speeds and the need to apply large amounts of energy, raising a number of difficult problems.

NEOShield: Starting in 2012, the European Commission began funding a 3.5 year program to study asteroid deflection. NEOShield does not have not enough money to launch any space missions, but they are studying how to stop an asteroid impact. As presented by Alan Harris of the German Space Agency, the NEOShield project leader, they are focusing on what they determined to be the three most promising options for stopping an impact: a thermonuclear blast, a kinetic impact, and a "gravity tractor" (whereby a spacecraft would gravitationally pull the asteroid with the spacecraft's own weak gravitational force, over a long period of time, slowly changing the asteroid's orbit). The goal is to design an asteroid deflection demonstration mission, though they will not have the funds to build and launch it under this program.

Lawrence Livermore (LLNL) and Los Alamos (LANL) National Labs: The energy density supplied by thermonuclear processes is the most powerful option currently available for the defense of Earth. Individuals at both LLNL and LANL have studied the use of thermonuclear explosives for either deflection or destruction of a threatening asteroid or comet. As in the case of kinetic impacts, the biggest uncertainty is how asteroids will respond to the thermonuclear blasts, depending on their composition, density, and other factors.

Dr. Paul Miller of Livermore gave an overview of the activity at LLNL, discussing both deflection and destruction scenarios, and his colleague Kirsten Howley discussed how a nuclear blast could be used to alter the trajectory of an asteroid without breaking it apart. Catherine Plesko of LANL discussed their work, examining how the radiation from a nuclear blast would interact with the surface of an asteroid or comet, and translate into a deflection.

EIRNS/Stuart Lewis

Lyndon LaRouche addresses a conference on April 13, 1983, on "new physical principles" such as directed-energy technologies for strategic defense.

Directed Energy Solar Targeting of Asteroids and exploRation (DE-STAR): Philip Lubin, University of California at Santa Barbara physicist, and Gary Hughes, California Polytechnic San Luis Obispo professor, presented their DE-STAR concept at one of the poster sessions. This would be a scalable, modular system, which would convert solar energy into electricity to power an array of lasers directed at a target. The key is the "phased array" technology, which allows for the multitude of lasers to be steered and focused to incredible energy densities at the target. If the system was large enough, it could produce a laser beam that would vaporize an area on the surface of the asteroid, with the vaporized material coming off the asteroid generating a thrust more powerful that the rocket engines of the Space Shuttle.

As with the observation systems, no one system will be the single perfect program, and a layered defense will be needed. As of today, the likely response to small near-Earth objects would have to be relatively fast, requiring the type of system being designed at the Iowa State ADRC. If there is a longer warning time, a kinetic impact mission could be an option, or thermonuclear explosives if the asteroid is too large. For long-period comets, a very large amount of energy would have to be deployed relatively quickly. The capabilities of Lawrence Livermore and Los Alamos would be taxed to their fullest extent, and that might not even be enough.

Again, the physical testing is key. There are still too many unknowns about how an asteroid will respond to a kinetic impact or thermonuclear blast. Participants at the conference emphasized that tests with kinetic impact missions can provide vital information for both thermonuclear and non-thermonuclear scenarios. But one test would not be enough. There is a wide range of different compositions and structures of asteroids and comets. Some are solid metal; others are rocky, with varying degrees of density, porosity, and homogeneity. Understanding how they will respond will require more tests and exploratory missions.

A last point of emphasis should be placed on directed-energy proposals. DE-STAR is the most recent in a short but important list of studies investigating the application of lasers to asteroid deflection. Directed-energy systems have many inherent benefits unmatched by kinetic systems, as Lyndon LaRouche insisted 30 years ago when he proposed the Strategic Defense Initiative (SDI), as it was adopted by President Reagan (but rejected by the Soviet Union and sabotaged from within the U.S. government).[6] They can act across space at the speed of light, whereas it may take days, or even years, for a spacecraft to travel to its target. Once a system is in place, each individual application of the system is relatively cheap when compared with designing, building, and launching a new dedicated space mission. These benefits could be critical for the challenge of very small asteroids, such as the one that impacted over Chelyabinsk, where a very rapid response would be critical.

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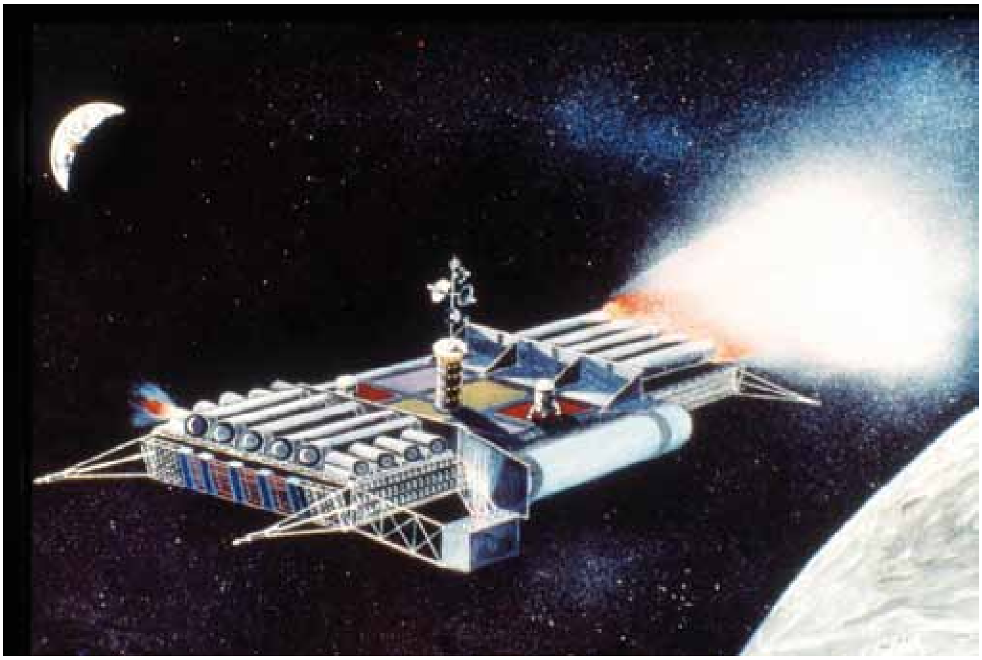
6. See for example, "Draft program for a U.S. beam program," *EIR*, Nov. 30, 1982.



Painting by space visionary Krafft Ehricke of a nuclear-powered freighter traveling between the Earth and the Moon.

Looking to the Future

The Planetary Defense Conference continued the legacy of similar conferences over the past two decades. Incremental progress was shown in many key aspects of planetary defense, and a depth of scientific knowledge and potential was demonstrated. The outstanding question is whether this potential will be developed to the extent needed.

Looking at the challenges ahead from the perspective of a science-driver, there are key, long-awaited areas of development that will revolutionize mankind's ability to defend life on Earth:

Advanced propulsion: While nuclear propulsion systems were already well on their way in the 1960s and 1970s, they were abandoned, and mankind is still bound by chemical propulsion. The energy densities of nuclear fission and thermonuclear fusion create the potential for space propulsion systems that are orders of magnitude more efficient, faster, and more powerful.

Directed-energy systems: Controlling directed-energy systems (as the general category of technologies was to be developed had the LaRouche-Teller version of the SDI gone through) would provide the basis for a revolution in planetary defense. Expensive, dedicated one-shot missions could be replaced with rapid speed-of-light action, available on command.

Moon-Mars infrastructure: Permanent bases on the Moon, and then on Mars (as envisioned by the late space visionary Krafft Ehricke), would revolutionize mankind's access to the Solar System. Resource development through lunar industrialization would be a first step, and expanding space infrastructure could tame asteroid orbits in the Solar System, as dams and irrigation systems tame rivers on Earth. Likewise, they will then be turned from a threat to a resource.

These were the basic areas identified and expected to be developed over a few decades at a 1992 Los Alamos NEO Interception Workshop, and even that was far behind what could have already been done had President Kennedy's vision been maintained. Today, the United States and other nations have suffered from decades of decline of the physical economy and skill levels of the workforce, and much of the potential to achieve these objectives has been squandered.

It is clear that a comprehensive defense of Earth from these threats is beyond the scope of any one nation, and requires a new level of strategic cooperation among nations. New space capabilities must be developed; new technologies are needed. Perhaps most important, new levels of trust and strategic cooperation among key nations—specifically the United States, Russia, and China—are needed to bring mankind into space for a peaceful, cooperative strategic defense of Earth.

Either mankind acts as one, for its defense, or we face the threat of extinction.

As was demonstrated in Flagstaff, an in-depth scientific capability exists, but it must be utilized and developed.

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