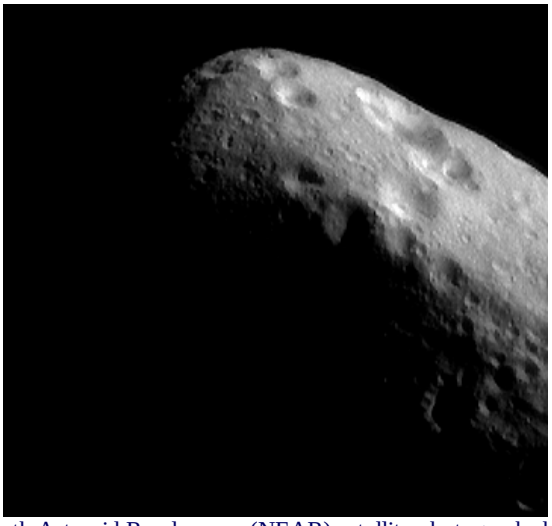
433 Eros, Orbiting An Asteroid Up Close

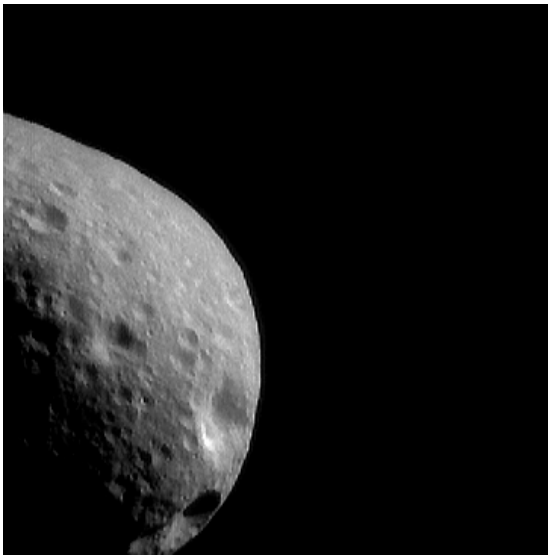


Near Earth Asteroid Rendezvous (NEAR) satellite photographs here and below of an asteroid called 433 Eros. NEAR moved into orbit around the 25 mile long asteroid on February 14, 2000 and took the first images from a range of 210 miles (330 km) above the asteroid's surface. Eros is about a hundred million miles from Earth in the asteroid belt between Earth and Mars. Photographs courtesy NASA and Applied Physics Laboratory, Johns Hopkins University, Baltimore, Maryland.

February 16, 2000 Baltimore, Maryland - It looks a bit like a 25 mile long, five mile wide potato. In one photo, it even resembles a Dutch shoe. Called 433 Eros, it's made out of iron and magnesium-bearing silicates and is now the focus of a NASA satellite called NEAR, Near Earth Asteroid Rendezvous. NEAR moved into orbit around Eros on February 14 and will stay there for the next year. Eros is one of the biggest asteroids in our Solar System circling between the earth and Mars. It's almost twice the size of Manhattan, measuring about 25 miles long and nearly five miles wide.

Some scientists expected Eros to show jagged edges from breaking off other rocky chunks in the asteroid belt - a belt of rocks presumed to be left over debris from the Solar System's formation 4.5 billion years ago. Another speculation is that perhaps a small planet might have existed between earth and Mars and been torn apart by a collision or planetary forces.

The first photographs of 433 Eros show a surprisingly smooth surface that is covered with craters and even craters on craters. That suggests great age and not a freshly fragmented asteroid. "The many craters visible serve as landmarks for navigating the spacecraft. Mission operators observe such features from different angles and use triangulation to calculate NEAR's position relative to the surface of Eros. The changes in position over time help to plot NEAR's course in orbit."



While the orbit of Eros currently does not cross the earth's, asteroid orbits can be influenced by Jupiter, Saturn and comets that come through the solar system. While the chance that Eros might strike earth is small, scientists say, there are a lot more rocks big and small that could come our way and might put the earth in harm's way. That's why scientists and the Defense Department want to study asteroids such as 433 Eros.

In fact, research in the 1990s by astrophysicist Jack Hills at the Los Alamos National Laboratory in New Mexico suggests that asteroids big enough to do serious damage can strike our planet at any time, with almost no warning given our current lack of knowledge about them. The consequences of an asteroid impact on Earth by something the size of Eros, or even half as big, would be catastrophic.

I asked Dr. Hills, while he is currently on sabbatical at the Space Telescope Science Institute in Baltimore to study 433 Eros data along with other scientists, what concerns him most about potential asteroid threats to earth.

Interview:

Jack Hills, Ph.D., Astrophysicist, Theoretical Astrophysics Group, Los Alamos National Laboratory, New Mexico and on sabbatical at the Space Telescope Science Institute, Baltimore, Maryland: "My primary concern is that one of these objects is going to hit us and we won't know anything about it. My biggest surprise was how damaging a tsunami is. What's relevant is that we know these objects exist. We certainly have the resources to find them. And this is not being done. I see it as potential for absolutely catastrophe damage though it's very small in any given year. I'm just afraid one will come some time that's serious.

And sneak up on us?

Yeah, unfortunately.

Any special reason for scientists to focus on Eros now?

It's one of the largest near earth asteroids. I guess I would have preferred a smaller and more typical one personally. But it is certainly the largest one. So, that may be of primary interest. And near earth also. It's not earth-crossing, so it's not going to hit us any time in the near future, although it could be nudged into an earth crossing or impact orbit in the future.

Meaning that if something else comes through the solar system and hits Eros or any of the asteroids in the asteroid belt, there is a possibility of a deflection towards earth.

That type of effect is not as important as the perturbations, the gravitational perturbations, exerted by Jupiter and Saturn and to a lesser extent the earth and others. Those gravitational perturbations gradually change the asteroid orbits over a period of time. And that type of perturbation principally by Jupiter and Saturn could then pump an asteroid into an earth-crossing orbit, an impact orbit.

Where is Eros right now in relationship to where the earth is revolving around the sun?

The closest approach of Eros is a little further out than the orbit of the earth. So, to make it into an earth impact orbit, it (orbit) would have to be a little more eccentric and go a little bit closer towards the sun which is the type of perturbation that Jupiter and Saturn tend to put on these objects.

What is happening right now with the NEAR satellite and how far is it from the Eros asteroid?

It's orbiting Eros (currently at about 210 miles). It's far enough away so that gravitational perturbations produced by the fact that it's not spherical but kind of a shoe-shaped or potato object doesn't wreck havoc with the orbit, but close enough so the tidal field of the sun doesn't pull it (NEAR) away from Eros. It's in a long, fairly safe orbit from Eros at this point.

You were quoted as saying in your asteroid research that any can become a 'sword of Damocles' and strike the earth at any time with almost no warning. Could you elaborate?

That doesn't apply to Eros.

But to other asteroids?

Yes, the difficulty is that there is a large number of earth-crossing asteroids, even larger than a kilometer across, that could end up killing a goodly fraction of people on the earth, any one of those. The basic problem at this point is that we only know and have cataloged a very small fraction of these objects. So any of these objects that are not cataloged or are not found yet, basically there is potential that we would not know about them at all until just before they hit the atmosphere of the earth. So, they would be almost instantaneous without any warning at all.

So, there is no way for us to pick up by visual sight or other monitoring device an asteroid coming near earth and crossing our orbit?

At the present time, there are telescopes not very many and not very big which take little frames using CCD camera of the sky in hopes of finding these objects. These are meant to find these objects years before hand and also to find the larger ones. What they do actually is take a very small fraction of the sky each month. They have to do that because they try to do long exposures to get very faint objects. The net result of that is if an object can't come then and is coming in right now and if it's outside of the frames they take each month, then they will miss it totally. In particular, they tend to observe in the direction that is exactly the opposite of the direction of the sun - not only because of the sun's brightness but those asteroids in that direction would look like full moons. If you looked more towards the sun, they would look more like crescent moons.

For the same distance, it would be much fainter. So, in general the surveys are limited to a very narrow cone in the direction exactly opposite the sun. So, if they came outside of that cone in the direction of the earth, we would miss it. And what is needed in addition to those types of surveys in my opinion is a series of smaller cameras that would cover almost all the sky several times a night. Then it would be possible to see objects a few hundred meters across several weeks before impact. Unless they happened with very bad luck to come very nearly in the direction of the sun. And I'm afraid that would be very difficult to see at the present time.

How does studying Eros help us understand how we might cope with a future asteroid on a collision path with earth?

Well, one of the things we do is to help determine how badly fractured it is, to

measure the porosity of it. If it were a solid rock, we pretty much know what it's density is. If it has a lot of fractures in it, then if it's a rubble pile with just a dust layer on it, its density would be much less than if it were a solid rock. And by measuring its average density you determine somewhat how badly fractured it is.

And also by looking at the rate in which the object, the potato shape causes the orbit to be perturbed, you can say something also about the distribution of mass in five of the asteroids. And that would also help us picture how badly fractured it is.

I mean, it's not ideal. Ideally, you would have some seismographs on the surface and then ping it and then look at the fractures that way. But this is a good start.

Looking at the photographs of Eros, it appears to be very smooth where there are not a lot of crater impacts.

You would expect rubble to collect around it with a layer of dust on top since it's a large earth-crossing asteroid that can pick up a lot of dust. The dust will make the rock look smooth. If Eros were small with very little dust on it, then it would look rougher.

What about the issue of its having broken off of something even larger?

It certainly looks like a fragment with a tortuous history! But, I think it's premature to talk about the details at this point.

Fragmentation, from an astrophysicist's point of view, involves trying to determine whether the asteroid was broken off from something bigger and whether or not it would break up a lot more if exploded by an atomic weapon trying to deflect it?

That's right. It might already be what we call a rubble pile which means that it's held together by gravity, not by material strength basically a bunch of loose blocks that are held together with gravity. And then it has rubble filling in the contact points and a layer of finer material, dust, eventually on top of that makes it look like a smooth object.

It certainly has big chunks in it that are reasonably solid, but what may look solid to the eye could have a lot of internal fractures in it. So strength is not very great and if you applied an explosion to it and hit it, then it would tend to come apart at those fractures. And that's the main concern.

Does the United States have any technology to counter an incoming asteroid?

No. First and foremost, you have to know they are coming in. And then you have to have the capabilities in hand that you can employ on a short enough time before they come in. So, we're just picking at it. Only a small fraction of the objects have been found. They all have to be found, the larger ones. And at the same time, we have to have the assets in place - at least to assemble them fast enough to deflect the object. Basically, nothing has been done on that latter end at all.

How vulnerable do you think earth is?

Well, we could all die tomorrow! We certainly are. An object several kilometers across could hit the earth basically any time. That would cause a significant fraction of the earth to die. What we have going for us is that even though the amplitude or size of the disaster is huge, the probability of it occurring in the current year, for instance, is very small. These large sized objects don't hit very often. We just don't know when the next one will hit.

Primarily, my research has been focused on calculating the damage these objects

would do as a function of their size, so we get some better idea of what type of resources we should put in to prevent these disasters from happening.

The Eros asteroid is about 25 miles long. What would happen if it hit the earth?

One half that size wiped out the dinosaurs. It would first of all probably produce a crater about 500 kilometers, 300 miles, or so across.

And then you would have the debris from that going out ten or twenty times that, big chunks of material. And then there would be a dust layer around the earth. The asteroid that killed off the dinosaurs left a layer of dust all around the earth about an inch thick. So, one this size is twice the size, twice the diameter, so it means about eight times the volume. So, instead of an inch layer of dust, you might expect eight inches of dust around the earth. And all this dust is up in the atmosphere in the top of the atmosphere and settles down. There will be total darkness on the earth. You can't see through eight inches of dust. For months! Maybe even years. So, the type of death that likely occurred in the Cretaceus-Tertiary that killed off the dinosaurs would be even more severe. Out at twenty times the diameter of the crater, you would have these big chunks coming in, probably continental fires.

And if this happens to hit the ocean, it's likely to be even worse. In addition to a crater being produced, a large tsunami would be produced. We have made some calculations that if a K-T impactor (like the one) that killed off the dinosaurs, for instance, hit in the middle of the Atlantic, the resulting tsunami would go all the way across Florida. And even one 1/2 that size would go about half way across Florida and then inundate even the western one-sixth of Florida by having a wave go through Cuba and Florida. So, that's illustrative of what could happen.

If something the size of Eros hit in the Atlantic Ocean, what would happen?

We know that for something the size of the K-T impactor that killed off the dinosaurs, the waves go all the way up to the Appalachians. An Eros-sized object would create an even higher flood inland.

The water from an Eros hitting the Atlantic would go past the Appalachians into the middle of the United States?

No, I don't think so. It will just go higher up in the Appalachians, they would protect it. We haven't made any calculations about what would happen in the Gulf of Mexico. I'm sure it would go into Texas much more than something the size of the K-T impactor. And the damage in Europe also would go up much more. But the Appalachians are like a barrier.

The Yucatan Basin between the United States and the Yucatan Peninsula is considered to be a crater produced by whatever impacted 65 million years ago and destroyed the dinosaurs, right?

Yes. There is a crater there found by a Mexican oil company a few years ago oil drilling which was a crater left over from the K-T impactor that killed off the dinosaurs. It was known even before then that it had to have hit somewhere near the Caribbean because there were thick layers of debris - not just the 1-inch material you find all over the earth - but thick layers that indicated that the crater was somewhere in the Caribbean and big chunks of material had been thrown out. So, we knew it was somewhere in there. Then the drilling found that. And other indications that that was the impact site as well, like the indications for tsunami along the coast of Mexico - the tsunami heights apparently became larger and larger as the waves approached the crater.

Your work and others' would imply that the impact on surface life is greatly affected by the dust and debris that cuts off sunlight reaching the

earth's surface?

That seemed to be the case for the dinosaurs, for the very large ones (asteroids). For the smaller ones, a few kilometers across there is also dust and that could lead to mass starvation around the earth, particularly. in the undeveloped countries. From where I work on tsunamis, for developed countries which have more resources and animals that eat and the seed they would normally eat, the animal would have much more reserve than undeveloped countries which are basically just eating the grain itself. It would be less affected by the dust except for the really big ones. And the tsunami might in fact be the worst thing that could happen - the water. It would scour even - one (asteroid) the size of the K-T impact hitting the Atlantic, it would basically scour the Eastern seaboard. It wouldn't be habitable for maybe hundreds of years. There would be salt basins there. Everything would have to start all over again.

Everything would be gone.

Everything would be gone! Not just dust gently settling and everyone starving, but all the resources remaining. After a tsunami of that amplitude, there is nothing left in that area.

The large crater in Arizona - what size object created that?

That was very small. That was a nickel-iron meteorite and that is much stronger than stone, so it penetrates much farther into the atmosphere before it starts breaking up. When they break up, it spreads out and the atmosphere slows it down. That object was probably between 20 and 60 meters across, a relatively small object.

But that is a large crater.

About a mile across. Not that large. It's a very clean, recent crater.

If people had been living in the U. S. when that object landed in Arizona, how far away would the impact have been felt?

The heavy debris would go out maybe 20 or 30 times the size of the crater, so 20 to 30 times out you would have big chunks of material coming down from the sky.

Would the ground shake?

There would be an earthquake, but for that size object, it would be relatively small. And there is no significant amount of dust ejected into the atmosphere. It would be noticeable, but it certainly would not cause mass starvation. The worst thing that would come from that would be the shock wave which would go out maybe tens of kilometers and basically flatten everything. A much smaller object that hit which was stone- and stone breaks up higher in the atmosphere - was in Siberia in 1908 in the Tunguska Valley in Central Siberia. And it basically flattened 20,000 square kilometers of forest which is much larger in area than Los Angeles and it's about the same area as Mexico City which is the largest city in the world. Much larger than Washington, D. C. or New York.

It flattened everything.

Yeah, it flattened everything in the forest.

Why don't huge impact events happen more often?

An object like that in Tunguska probably happens about every 300 years. It recovers quite easily. In Tunguska, it's in Siberia. You can still see the damage. There is no crater formed because it was stone and it broke up up in the atmosphere and the energy involved dissipated in the atmosphere.

In case of the object in Arizona, it was about the same size object, but it was stony iron, so it fragmented only a very short distance from the ground and made a crater. So that type of event as maybe every 50,000 years.

The nickel-iron ones are more rare. They are only 3% of the total population.

But those are the asteroids that could come around every 300 years?

Yeah, something of that order and basically if they hit land, they would cause a flattening like that. If they hit the ocean because they dissipate their energy in the atmosphere, they wouldn't produce very much, not a tsunami.

The Defense Department indicates asteroids are enough threat to organize more monitoring of Near Earth-crossing asteroids?

I don't think there is going to be a coherent body such as the Defense Department doing this. There is a realization that from the ground up there is a problem and scientists like myself have been working on it and presenting the problem. But as of now, there isn't any coherent body that has taken charge of it and said: here's the problem. Let's solve it. Which I wish would occur, but it hasn't occurred yet. There's some effort to find these through NASA, but mostly the Air Force's Lincoln Labs - to find them. And there is some effort now through NASA to look at a few of these objects, characterize them so we have a better idea what they are like.

You are saying that right now there is no official government body focused around the asteroid impact problem. Could there be a coalescence of a more formal government project around the Near Earth research connected with Eros?

I think there should be and probably has to be some organization or collaboration to solve the problem. For finding these objects, NASA has taken a certain amount of lead, but NASA is a research institution. It's not something that funds long term studies. This is more like what the Air Force does for space debris. It has capabilities all around the earth to look for space debris and probably could be refocused to look at five asteroids like Lincoln Labs is doing for them.

NASA is very good at research and development and for characterizing these objects we certainly need a NASA to go our and look at them as is being done for Eros and studying their structure. Other things need to be done, I think, like landing a seismograph on them and pinging on them so we know the internal structure of them much better. And then on the other hand, we also need some coherence so if we have these objects, we have the equipment in place or know how to put the equipment in place in a short enough time you actually deflect these objects. And I think ultimately, it will have to be the Department of Defense that will take the lead in this.

You said earlier, we are vulnerable and are even more so if we do not get a list of what is out there that is large and could cross the earth's orbit. Otherwise, we're sort of flying blind around the sun not knowing what's headed our way.

That's right. We're taking a chance. We're gambling. The right thing to do is to find these objects. If hasn't occurred recently and maybe it won't occur in the next few hundred years, but it could happen tomorrow. So, you have almost infinite danger, but the probability in any given year is very small.

What are the very nearest misses in the last few years?

The ones we don't know about. In fact, we only know a very small fraction of the asteroid population. And there is an object the size that hit Tunguska in 1908 and passes within the orbit of the moon every two weeks! And we know

only the smallest fraction of those objects. We're missing them, so even though they are kilometers across, undoubtedly there have been encounters by a century and we are simply blissfully ignorant of them.

What would happen if something large hit the moon?

That's no problem. These objects are very small compared to the orbit of the moon. They would produce craters and the moon is covered with numerous craters from previous impacts. And it's still orbiting the earth at a safe distance. So another crater is not going to cause that much problem.

But if objects pass within the orbit of the moon every couple of weeks and it's only about 242,000 miles from earth, what is the likelihood that something big could come near the earth in the next 25 years?

It depends on the size of the object. Something like the Tunguska one, there is possibly one chance in ten that something that size will actually hit the earth in 25 years. If you're talking about something a kilometer across, it's far less likely.

Is there anything our government could do if we got a warning that a kilometer-wide asteroid was suddenly coming our way?

If we had just a few weeks all we could do is evacuate from the area. Time scale is probably a few years right now because the equipment isn't locked in place to take care of it. People have made estimates that if there was a rocket with a nuclear explosive on it ready to go, it could deflect asteroid with as little as a week's warning if it's only one kilometer across. If it's several kilometers across, you would have to go several weeks warning and eventually if it gets larger, it would have to be several months warning. But right now, the equipment is not in place, so the time table required is what it takes to get such a system set up. Which is years, unfortunately.

Which is easier: Launch a missile from the earth to intercept and explode an in-coming asteroid? Or launch a vehicle toward the asteroid in order to land a deflecting device on the asteroid in outer space?

It's much easier to put an explosive near it because then the vehicle would have to slow down accurately for a landing. You just have to approach near the asteroid and set off the explosion.

The percussion of the explosion could force the asteroid off in another orbital path?

Basically the explosion, the shock wave, hits the asteroid and blows off material. So it acts like a rocket, all this debris flying off, and pushes the asteroid in the opposite direction.

If we did have a warning tomorrow that something big was arriving in 6 months, what is the first action humans could do?

I don't think 6 months is enough time. If people were pushed hard enough, we might be able to do something in 6 months. I think generally, we need a few years.

So nothing could be done if we have only a few months?

We can evacuate the immediate vicinity of the projected impact so there wouldn't be anyone in the vicinity of the crater. If it's hitting in the ocean, then it certainly would be prudent to get people away from the water and up into high ground. The number of deaths anyway would be mitigated. The economic damage from a tsunami, for instance, would hardly be mitigated at all, or from a crater. You don't move buildings. So, that type of damage would be unaffected. You'd have to deflect the asteroid to prevent the economic damage.

If we had a year's warning, is there any technology we could apply now to deflect a large asteroid?

Yeah, the explosives exist, the rockets exist, but they have to have the upper stages properly and the type of homing devices required for this mission to intercept. All this takes time and planning and it hasn't been done.

Have we ever tried to do such an experiment out in space that's been classified from public knowledge?

No, no. There was a program that was unfortunately vetoed by President Clinton. Clementine II which would have been a US Air Force mission and would have gone to a number of asteroids and put probes into the asteroid which the mother craft would look at and see what affect it had on it.

First goal of Clementine was to photograph the surface of the moon. The second part was to photograph an asteroid, correct?

Clementine I was launched to go to the moon and then be deflected out of the earth's orbit and intersect an asteroid. Unfortunately because of software problems, it only did the moon. Clementine II was another mission, a totally separate mission, which would have gone to several Near Earth asteroids which would have been hit by the mother craft with a number of projectiles, probably three or up to five. And these projectiles would be fired into the asteroid and then the mother craft would photograph the impact sites to see how much damage was done. We were to study a number of asteroids that way and it would have been practice for intersecting an asteroid.

Why was it canceled?

The concern of the Clinton Administration was that this looked too much like an anti-ballistic missile which they thought might violate international treaties. However, it would be intersecting these objects on time fields of months and years. But for a missile, you're talking about minutes."

Websites:

http://www.spaceref.com/focuson/near/

http://www.space.com/

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