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POSSIBILITY OF A MOON BASED TERRESTRIAL DEFENCE SYSTEM FOR THE EARTH

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Gravity of the NEO Threat

In the NEO Survey Act, US Congress made the following findings:

- **Near-Earth objects (NEOs) pose a serious and credible threat to humankind, as many scientists believe that a major asteroid or comet was responsible for the mass extinction of the majority of the Earth's species, including the dinosaurs, nearly 65,000,000 years ago.**
- **Similar objects have struck the Earth or passed through the Earth's atmosphere several times in the Earth's history and pose a similar threat in the future.**
- **Several such near-Earth objects have only been discovered within days of the objects' closest approach to Earth, and recent discoveries of such large objects indicate that many large near-Earth objects remain undiscovered.**
- **The efforts taken to date by NASA for detecting and characterizing the hazards of near-Earth objects are not sufficient to fully determine the threat posed by such objects to cause widespread destruction and loss of life.**

- 2006 Near-Earth Object Survey and Deflection Study Draft of NASA

Potentially Hazardous Objects (PHOs)

- **Asteroids:**
  - Moving objects that appear as a star-like point of light.
  - Unknown until about 200 years ago when telescopes became powerful enough to detect them.
  - Relatively rocky or metallic objects without atmospheres.
  - asteroid belt— the ring of rocks that orbits between Mars and Jupiter.
- **Comets:**
  - Moving Objects that appear diffuse or those that have visible tails.
  - Because of their distinctive tails, people have known them since ancient times.
  - Composed in part of volatiles such as water ice that vaporize when heated.
- **Comets far from sun look like asteroids.**
- **A PHO is an object in our solar system that passes within 0.05 AU of Earth's orbit and is large enough (more than 50 meters) to pass through earth's atmosphere.**
- **Approximately, 21% of the NEOs of any given size class are expected to be potentially hazardous.**
- **The estimated population of NEOs measuring 1 km and larger = approximately 1100.**

Meteors & Meteorites

- **Meteors:**
  - The short, white trails across the sky that we call "shooting stars."
  - Caused by small pea-sized pieces of inter-planetary dust that burn up when they slam into the Earth's atmosphere at high speeds.
  - Meteor showers happen when Earth passes through the orbital path of a comet that left a lot of dust behind. Earth plows through the dust, and the particles form meteors as they hit the atmosphere. Occasionally a small rock may fall through the atmosphere, causing an extremely bright and colorful streak across the sky called a fireball. (These are often mistaken for comets, but comets do not streak across the sky quickly; they are usually visible for many days.)
- **Meteorites:**
  - Sometimes fireball rocks are not completely vaporized, and they impact Earth's surface. A rock that fell from space this way is called a meteorite.
- **As known till date, Meteors & Meteorites are not hazardous but they may become if big enough.**

Impact of changing universe conditions on the collision probability of NEOs with Earth

- **What is changing (Some factors)?**
  - Distances among the heavenly bodies due to expansion of earth.
  - Creation of new stars and death of old stars (resulting in creation of black holes).
  - Creation of new asteroids & meteorites?
  - The path of asteroids, comets and meteorites due to changing positions of different bodies.
- **Impact**
  - **Though probability of collision of an NEO with Earth may go down with time with increasing distances among heavenly bodies (expanding universe), it will never approach zero due to changing conditions in the universe.**

NEO Strategies & Findings of NASA (till May 2007)

- Combining optical ground-based observatories with dedicated ground based asset will help.
- Space-based IR systems, combined with shared ground-based assets will also help.
- Space systems have additional benefits and risks over ground-based alternatives and are generally more capable than ground-based alternatives.
- Radar systems cannot contribute to search of PHOs but they can rapidly refine tracking.
- Determining an object's mass and orbit are required to determine whether it represents a threat and to inform deflection alternatives.
- Nuclear standoff explosions are assessed to be 10-100 times more effective than the non-nuclear alternatives .
- Kinetic impactors are the most matured approach and can be used against small, solid objects.
- Slow push deflection techniques are the most expensive and their ability to both travel and to divert a threatening object is limited unless mission durations of many decades are available.
- Deflection campaigns may need to be 100-1000 times more reliable than current space missions to meet mitigation requirements.
- 30-80% PHOs are in orbits beyond the capability of current or planned launch systems. Therefore to deflect these objects, swingby trajectories or on-orbit assembly of modular propulsion systems may be required to augment launch vehicle performance.

Major Challenges in defence against Asteroids & Comets

1. Spotting the comet or asteroid (which is really going to collide with earth) at a safer distance and as early as possible so that proper action can be taken.
2. To take action with no damage to our own environment.
3. to deflect or destroy the comet or asteroid at such a distance and angle that the deflected body shall not collide with any other body of interest or debris shall not cover our earth and shall not affect ourselves.

Moon as a Surveillance base for a terrestrial defence system against comets & asteroids

- The moon offers an optimal alternative to tackle the challenges in previous slide.
- Its distance from earth is approx. 3,84,403 km. which is sufficient enough to spot a comet or asteroid (which is going to strike us) much earlier through a telescopic observatory established on moon.
- Observation from moon will be much clearer and longer range due to nil atmospheric effects.
- However, Two observatories will be required if sunlight is to be used as one side of moon gets sun only for half of a month and if surveillance is required round the earth.

Moon as the Action base for a terrestrial defence system against comets & asteroids

- The absence of environment on moon can make the use of very high intensity Particle Beam Weapons (using hydrogen atom) or Laser Directed Energy Weapons quite possible to destroy the heavenly body completely at a much safer distance than it is possible to do it from earth.
- Even missile based systems as impactors to deflect the PHOs can work better on moon due to low gravity (and hence fuel saving).
- Also, nuclear denotation near moon to kill or deflect an approaching comet is much safer.
- Possibility of the debris affecting us is much less if the moon based system is established and used.
- PBWs & LDEWs can mostly destroy a body in line of sight while missiles can deflect or destroy non line of sight bodies as well. In fact a combination of PBWs, LDEWs and missiles can ensure safeguarding against all types of terrestrial threats.
- Also, operation from moon is not as difficult as it is from mars or any other satellite or planet.

Laser DEWs & PBWs as deflectors?

- Though missiles, space crafts or nuclear detonators are established deflectors, a question arises if Laser Directed Energy Weapons or Particle Beam weapons can also be used as deflectors to change the path of an asteroid or comet?
- **Yarkovsky Effect:**
  - The diurnal heating of a rotating body would create a force due to the escape of thermal radiation as the sunlit side rotated into darkness and cooled.
  - As the heated surface turns away from the sun, photons are radiated from the asteroid as it cools.
  - Photons carry momentum off the asteroid and, due to Newton's Law provide a pushing force.
  - Though the force produced by the photons is extremely small, over a long period of time, it can change an asteroid's orbit.
- **Laser or PBW enhanced Yarkovsky effect:** Though paint or other material covering on asteroid is suggested as enhanced Yarkovsky, Laser or PBW irradiation over long term can further enhance Yarkovsky effect and provide better deflection. However, experimental results in this regard have yet to come up.

Possible Opposition of Moon based scheme

- Some people may oppose it who wish to colonize moon and make it another place for mankind. The finding of vast amount of ice on moon provides a remote possibility of creation of suitable atmosphere there for creation of a new civilization.
- But even this approach does not rule out the role of moon for defence of earth completely. Some fine tuning can make both the possibilities work well together.
- Earth will still remain our base planet and safeguarding it our main priority. Once a civilization on moon comes up, we can look for a similar scheme to safeguard it as well.

Challenges ahead in realizing a moon based Terrestrial Defence system for Earth

- **Political Challenges:** Getting the world convinced.
- **Landing on moon (Man or Robotic) and establishing such a base:** It will be difficult as no one has performed such physical and long work on moon surface.
- **Implementation Challenges:** All three options like
  - –Building complete system on earth and taking it to moon,
  - –Taking components on moon and assemble them there or
  - –Build components and system there itself using materials available there.

  seem to have their own challenges, though middle option seems feasible.
- **Moon Quakes:** These are quite frequent and can severely damage the instruments & structures there.
- **High Temperature Difference:** Instruments on the moon will have to face the huge temperature difference there. The temperature on the moon varies from -387 Fahrenheit (-233 Celsius), at night, to 253 Fahrenheit (123 Celsius) during the day. Designing instruments to tackle such huge temperature differences is a challenge. However, a Temperature difference based mechanism to generate power on moon can also be thought out to power our instruments.
- **Controlling a Moon based system from earth:** This may be difficult in bad weather conditions.

Advantage and Challenge due to locking of moon's face with earth

- The locking of moon's face with earth due to which we always see the same side of the moon is going to offer both an advantage and a challenge.
- Advantage is that we only have to establish a base on the opposite side of the one facing us to keep a watch and deflect or kill something truly going to be dangerous for us.
- But the challenge is that we do not know much about the opposite side. However, Indian "Chandrayan –I" mission is trying to uncover other side as well.
- However, proper direction to missiles can always be given and hence the challenges can be met by putting base on our side as well.

Conclusions

- **Moon is a suitable base for a defence system against Potentially Hazardous Objects (PHOs like comets and asteroids) aiming to collide with earth.**
- **However, there are a number of challenges ahead in realizing such a base. Authentic data based proper Cost-Benefit analysis with other alternatives is required.**
- **A joint effort among several nations will be required for such a project.**

Further studies required in this area

- What can be done and built on moon and what to be done on earth?
- Moon has got a lot of resources but utilization of those resources is still quite a difficult challenge.
- Reliability of such a defence system is another issue.
- Maintenance of this system on moon may become a difficult and costly problem.
- Proper cost benefit analysis with other options like earth or space station or Mars based ones including reliable data received through further moon explorations can be helpful. Indian “Chandrayan” Missions can also help in this regard.
- Studies on Moon Quake & temperature difference resistant structures and instruments is also required.
- Most Conditions on moon offer both challenges and new opportunities. Proper analysis is a must.

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Thank You !