Tressler LLP

Asteroid Mining, Space Debris and Planetary Defense

PRESENTED TO: AIAA

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Introduction

Asteroids

- Greek word for “star-Like”
- Small, rocky objects that orbit the sun, like planets, but much smaller
- Larger asteroids are typically called planetoids
- Vast majority orbit within main asteroid belt between Mars and Jupiter
- Other orbital families exist, including
  - Near-Earth objects (NEO), near-Earth Asteroids (NEA) and a subtype, Easily Recoverable Objects (EROs)

Asteroid Mining

- Resource-rich space rocks
- Contain metals, rare minerals and other elements, including:
  - Gold
  - Platinum
  - Iron
  - Titanium
  - Hydrogen
  - Oxygen
  - Nitrogen

Asteroid Classifications

- Primarily composed of mineral and rock
- The majority fall into three main categories:
    1. C-Type (Carbon)
    2. S-Type (Silicate)
    3. M-Type (Metallic)
- Sizes of asteroids vary

Mining Purpose and Potential

- Extract and ship valuable metals back to Earth
- Earth reserves could become exhausted
- “Steppingstones to the Solar System.”
- Human space travel becomes easier and cheaper
- Incentivize development of infrastructure and transport in the nearby Solar system
- Iron metals and other common ones used for construction in space
- Provide data for the search for extraterrestrial intelligence

Possible Mining Options

1) Bring raw asteroidal material to Earth to use
2) Extract and ship processed materials back to Earth
   - Produce propellant for return trip
3) Transport the asteroid to safe orbit around the Moon or the Earth or to the International Space Station (ISS)

Extraction Techniques

1) Surface Mining
2) Shaft Mining
3) Magnetic Rakes
4) Heating
5) Mond Process

Potential Targets

Asteroid	Est. Value (US$billion)	Est. Profit (US$billion)	$\Delta V(km/s)$	Composition
Ryugu	83	30	4.663	Nickel, iron, cobalt, water, nitrogen, hydrogen, ammonia
1989 ML	14	4	4.889	Nickel, iron, cobalt
Nereus	5	1	4.987	Nickel, iron, cobalt
Bennu	0.7	0.2	5.096	Iron, hydrogen, ammonia, nitrogen
Didymos	62	16	5.162	Nickel, iron, cobalt
2011 UW158	7	2	5.189	Platinum, nickel, iron, cobalt
Anteros	5,570	1,250	5.440	Magnesium silicate, aluminum, iron silicate
2001 CC21	147	30	5.636	Magnesium silicate, aluminum, iron silicate
1992 TC	84	17	5.648	Nickel, iron, cobalt
2001 SG10	3	0.5	5.880	Nickel, iron, cobalt
Psyche	27.67	1.78	-	Nickel, iron, cobalt, gold [57]

Space Debris

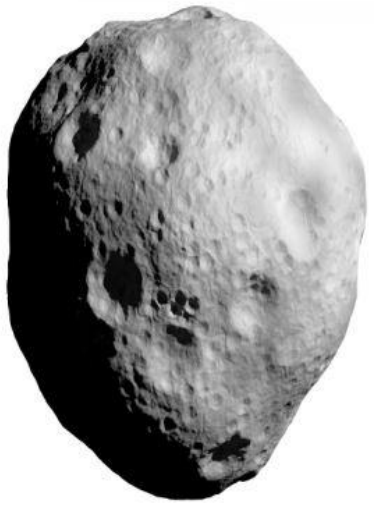
Commonly also known as:

- **Space Junk**
- **Space Waste**
- **Space Pollution**

Definition: **"Defunct human-made objects in space which no longer server a useful function."**

Classification of Space Debris

1. Artificial Space Debris
   - Non-functional spacecraft
   - Abandoned launch vehicle stages
   - Mission related debris
   - Fragmentation debris
2. Natural Space Debris
   - Meteoroids = fragments from comets or asteroids



Locations of Space Debris

- Earth Orbit (Geocentric Orbit)
  - Any object orbiting the Earth
- Types of Earth Orbit:
  1) High Earth Orbit (HEO)
  2) Medium Earth Orbit (MEO)
  3) Low Earth Orbit (LEO)

High Earth Orbit (HEO)

- Higher than 35,786 km (22,236 mi)
  - The altitude of Geosynchronous Orbit
- In HEO, orbital periods are greater than 24 hours
- Orbital velocity of less than 1,000 mph
- Some weather and communication satellites
- Rarely used orbit

Medium Earth Orbit (MEO)

- Between 2,000 and 35,7586 km
  - Essentially, more than 1,243 miles above Earth's surface
- Orbital periods range from 2 to nearly 24 hours
- Home to navigation and specialty satellites

Low Earth Orbit (LEO)

- Between 180 and 2,000 km (1,200 mi)
  - Essentially, less than 1,243 miles above Earth's surface
- Most scientific satellites are located here
  - NASA's Earth Observing System (EOS)
  - International Space Station (ISS)
  - Hubble Space Telescope

Low Earth Orbit (cont'd)

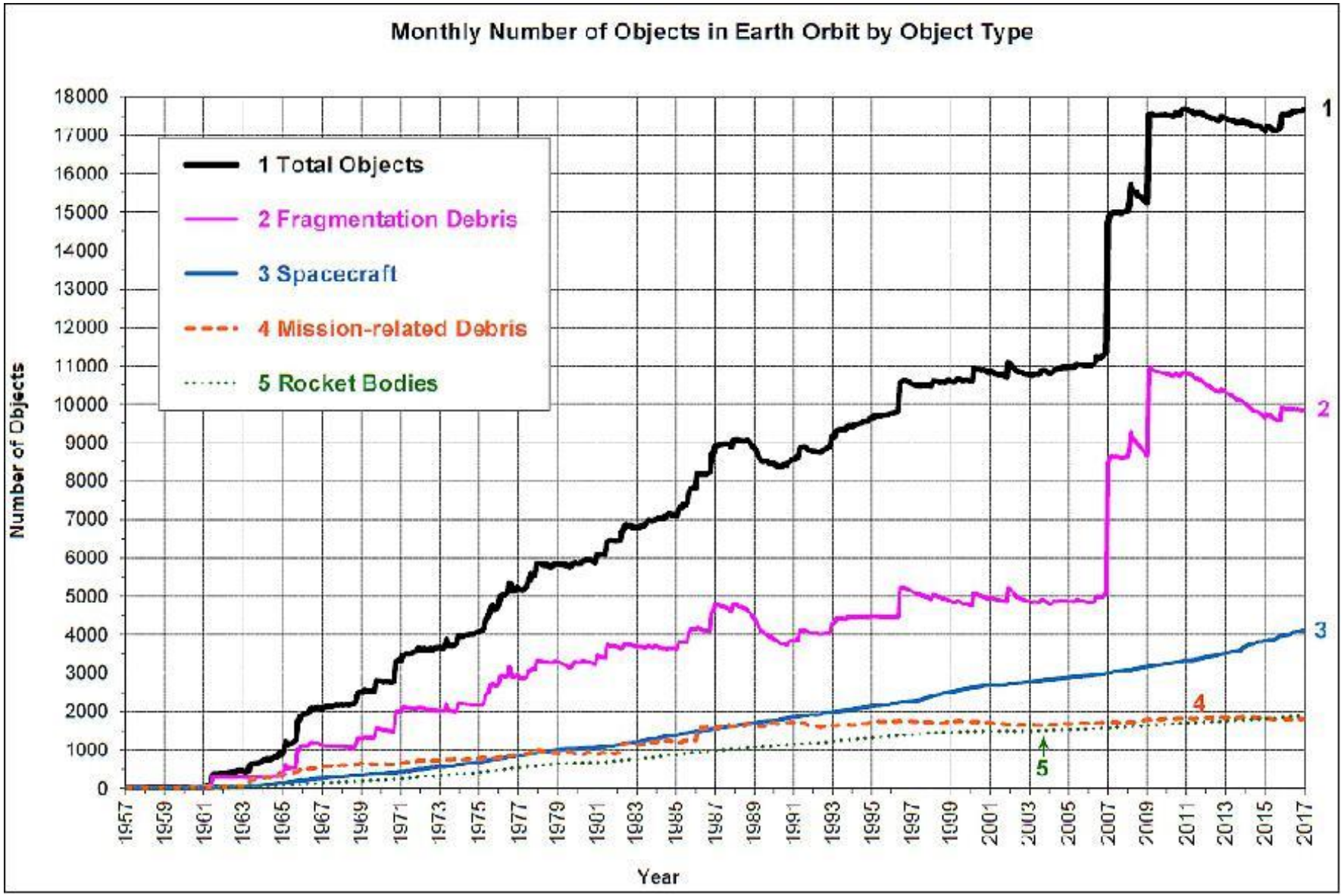
- LEO also where space debris is especially concentrated
- Asteroids (fragments) also exist in LEO
- Orbital Period of 128 minutes or less
- Orbital velocity of approximately 17,000 mph
- Objects in an elliptic orbit can vary in altitude and speed

SpaceX's Starlink

- LOE is where the Starlink satellites are being placed
- Satellite constellation to provide broadband internet
- 538 satellites in orbit
- Planning to have more than 1,200 satellites

Amount of Space Debris

- True amount unknown
- In October 2019, reportedly 20,000 objects in orbit
  - These are just the ones that can be tracked
- More than 128 million smaller than 1cm
- 900,000 between the size of 1cm-10cm
- 34,000 pieces larger than 10cm



Source: NASA Orbital Debris Program Office

Tracking

- The E.U and U.S use two different tracking systems:
  - Space Surveillance and Tracking (SST) system – European Union
  - Space Surveillance Network (SSN) – United States
    - Capabilities are generally limited to object 10cm and larger

Space Debris Threat

- Artificial debris poses a growing threat to functioning satellites
- However, natural debris like asteroids also pose a threat
  - Existing asteroids, or fragments, may collide with other asteroids, artificial debris and functioning satellites
  - Easily Recoverable Objects (ERO) are considered likely candidates for mining
  - Plans to relocated Asteroids to LEO for mining
  - Particles shed by the transplanted asteroids during mining
  - May create more and more debris
  - Prevent the use of valuable orbits in the future

Kessler Syndrome

- Proposed by NASA scientist Donald J. Kessler in 1978
- At that time, Kessler found that 42 percent of cataloged debris was the result of 19 events, primarily explosions of spent rocket stages
- Essentially a chain reaction theory of exploding space debris
- Collisions between objects could cause a cascade in which each collision generates space debris that increases the likelihood of further collisions

Near-Earth Objects

- NEO is any small Solar System body whose orbit brings in in proximity with Earth
- If NEO’s orbit crosses the Earth's, and the object is larger than 140 meters (460 ft) across, it is considered a potentially hazardous object (PHO)
- Most known PHOs and NEOs are asteroids, also known as near-Earth Asteroids (NEA)
- Over 20,000 known NEAs

Earth Collison Threat

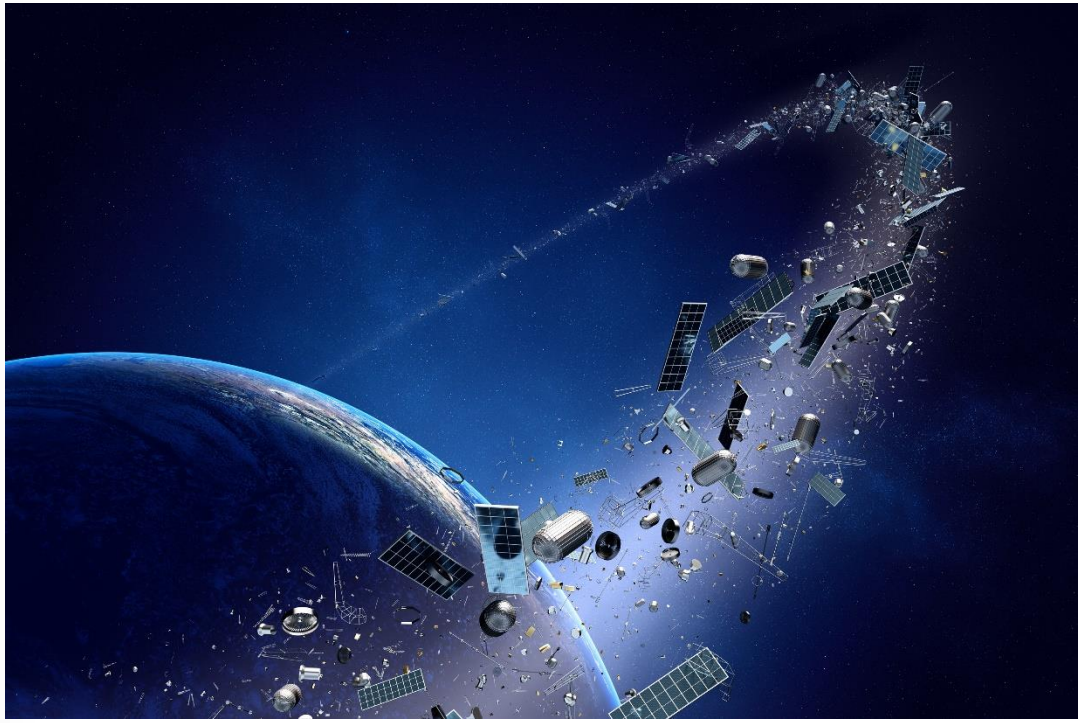
- Orbital changes can lead to collisions with Earth
  - The elliptical orbit or trajectory of any cosmic body (i.e., asteroids, comets, etc.) can be permanently altered by the gravity of other asteroids and/or planets.
- On April 13, 2029, we might experience just that because asteroid Apophis will pass below the orbit of low earth orbit (LEO) satellites and its exact trajectory cannot be predicted.

Asteroid Impact Avoidance

- Spaceguard
  - Discover, catalogue and track
- NEOCam
- Kinetic impact
  - NASA's Double Asteroid Redirection Test (DART)
- Capturing small celestial objects
- Nuclear-powered laser
- Nuclear explosives
- Spacecraft Propulsion

Legal Framework for Use of Space

The International Community, the European Space Agency and the United States have all created guidelines for mitigating damage due to space debris and asteroids.



General Framework

International Treaties, Policy and Guidelines

- Treaties
  - Treaties on Principles Governing the Activities of States in the Exploration and Use of Outer Space – 1967 (“Outer Space Treaty”)
  - Convention on International Liability for Damage Caused by Space Objects - 1972(“Liability Convention”)
  - Convention on Registration of Objects Launched into Outerspace- 1976 ("Registration Convention")
  - Agreement Governing the Activities of States on the Moon and Other Celestial Bodies- 1984 ("Moon Treaty")

Outer Space Treaty

Article VI

State Parties to the Treaty shall bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. . .

Article VII

Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the Moon and other celestial bodies, and each State Prarty from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on Earth, in air space or in outer space, including the Moon and other celestial bodies.

Space Debris Mitigation

International Space Debris Mitigation Guidelines

- The UN Committee on the Peaceful Uses of Outer Space's (UN COPUOS) Space Debris Mitigation Guidelines
- The European Space Agency's Inter-Agency Space Debris Coordination- IADC Space Debris Mitigation Guidelines
- The International Organization for Standardization (ISO)
  - ISO 24113, 2019 "Space Systems – Space Debris Mitigation Requirements."
  - ISO 16158 "Space Systems –Avoiding Collisions with Orbiting Objects"
- The International Law Association (ILA)- Draft Convention

U.S. Space Debris Mitigation

National Space Policy

Commercial Space Launch Competitiveness Act (2015)
SEC. 109. ORBITAL TRAFFIC MANAGEMENT- Providing for the initiation of a study of orbital traffic for the purposes of orbital debris mitigation.

- Presidential Policy Directive 4 (2010)
- Space Policy Directive 1-Reinvigorating America's Human Space Exploration Program
- Space Policy Directive 2-Streamlining Regulations on Commercial Use of Space
- Space Policy Directive 3-National Space Traffic Management
- Space Policy Directive 4-Establishment of the United States Space Force

U.S. Space Debris Mitigation

National Standards

- United States Government Orbital Debris Mitigation Standard Practices (adopted 2001)
- NASA Procedural Requirements for Limiting Orbital Debris (NPR 8715.6A)
- NASA Process for Limiting Orbital Debris (NASA Standard 8719.14A)
- DoD Directive 3100.10 (Space Policy)
- DoD Instruction 3100.12 (Space Support)

U.S. Space Regulation

U.S. Regulation- Federal Aviation Administration (FAA)

The FAA is regulates all commercial space transportation. Specific FAA regulations include the following requirements that an applicant must demonstrate in part:

- 14 CFR §415.39- Safety at end of launch
- 14 CFR §417.129- Flight safety system test data

U.S. Space Regulation

U.S. Regulation- Federal Communications Commission (FCC)

The FCC regulates licensing of satellite communications:

- 47 U.S.C 301, 305
- 47 C.F.R. 5.64
- 47 C.F.R. 25.114
- 47 C.F.R. 97.207
- 47 U.S.C 308
- FCC Order (FCC 04-130)
- Notice of Proposed Rule Making (IB Docket No. 18-313; FCC 18-159)- “Mitigation of Orbital Debris in the New Space Age”

U.S. Space Regulation

U.S. Regulation- National Oceanic and Atmospheric Administration (NOAA) Regulation of Private Remote Sensing

NOAA regulates licensing for operation of Private Remote Sensing, Title 51 U.S.C. 60101, 15 CFR § 960.4

- The license requires that operators, “upon termination of operation of operations under the license, make disposition of any satellites in space in a manner satisfactory to the President,” in accordance with Section 202 (v)(4) of the Act.

Legal Liability

Claims under the Outer Space Treaty and the Liability Convention

- 1977 Cosmos 954- Soviet Union ultimately paid CAN $3,000,000 to Canada in connection with a satellite with a nuclear reactor core under a settlement agreement. Canada spent CAN $12,000,000 and sought CAN $6,000,000.

- 2009 Iridium 33 Collision- An inactive Russian satellite collided with an active U.S. commercial communications satellite. The U.S. Satellite was not registered with the United Nations, which potentially raises questions under the Liability Convention. However, the parties settled outside of the framework of the Liability Convention.

- 2007 Chinese ASAT Test resulting in excess of 35,000 pieces of space debris.

- January 2020- Near miss between non-operational satellites

Asteroid Mining

Is it legal?

- **Definitely- Maybe**
- **And what did they mean in 1967?**

Asteroid Mining

Outerspace Treaty-Article I

The exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the intrests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.

Outer space, including the Moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.

There shall be freedom of scientic investigation in outerspace, including the Moon and other celestial bodies, and States shall facilitate and encourage international co-operation in such investigation.

Asteroid Mining

Outerspace Treaty-Article II

Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.

Asteroid Mining-US Law

Commercial Space Launch Competitiveness Act (2015)

§ 51303. Asteroid resource and space resource rights

“A United States citizen engaged in commercial recovery of an asteroid resource or a space resource under this chapter shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States.”

Asteroid Mining

- The U.S. has taken the position that a private entity may take ownership of the resources extracted from the moon and other celestial bodies but cannot assert ownership or sovereignty over the moon and other celestial bodies under the Outer Space Treaty

- The Case of Gregory W. Nemitz v. United States of America
  - Mr. Nemitz file a claim for ownership of Asteroid 433. The claim was recorded and published by the Archimedes Institute and he also filed his claim with the State of California under the Uniform Commercial Code.
  - When the NEAR Shoemaker spacecraft landed on Asteroid 433, Mr. Nemitz sent NASA a bill for parking and storage fees at a rate of 20 cents per year.
  - Mr. Nemitz subsequently filed suit against the United States asserting his private property rights on Asteroid 433.
  - The Court dismissed the action for failure to state a claim because he could not demonstrate that US law or any International Treaty established his right to assert a private property right on an asteroid.

Asteroid Mining Damage

Asteroid Mining

- **If caused by mining, the liability would fall on the State that has responsibility for the entity conducting the mining operations.**

NASA Action Plan for Asteroid Diasters

National Near-Earth Object Preparedness and Strategy and Action Plan

By Interagency Working Group for Detecting and Mitigating the Impact of Earth-Bound Near-Earth Objects of the National Science & Technology Counsel (June 2018)

Goal 1: Enhance NEO Detection, Tracking, and Characterization Capabilities
Goal 2: Improve NEO Modeling, Prediction, and Information Integration
Goal 3: Develop Technologies for NEO Deflection and Disruption Missions
Goal 4: Increase International Cooperation on NEO Preparation
Goal 5: Strengthen and Routinely Exercise NEO Impact Emergency Procedures and Action Procedures

NASA –FEMA & Asteroid Disasters

Planetary Defense Coordination Office:

NASA and FEMA have undertaken Asteroid Impact Emergency Planning Exercises, which include:

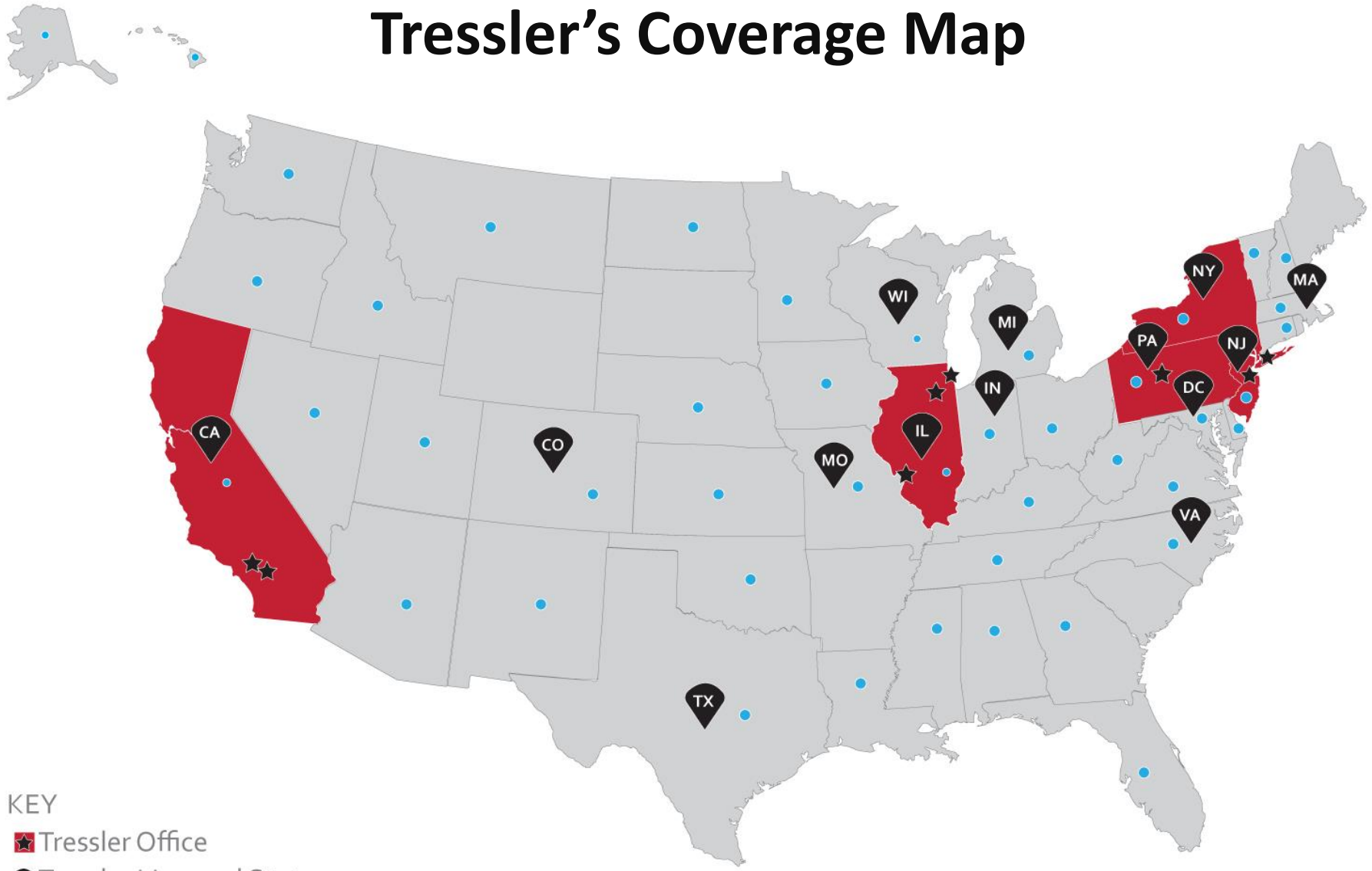
- Collection, analysis and sharing of data
- Simulation of a potential asteroid event
- Observation
- Deflection
- Analysis of impact footprint models, population displacement, effect on infrastructure
- Provisions of useful and timely information to public
- Evacuation
- Plans to include local and state emergency response teams

NASA Double Asteroid Redirection Test

In 2022, NASA will initiate the first full scale Double Asteroid Redirection Test (DART) where the DART spacecraft will crash into the asteroid to change its course.

DART is the first mission developed for NASA's Planetary Defense Coordination Office established to detect and warn of potential asteroid collisions and to determine who to mitigate such hazards.

Tressler's Coverage Map



THANK YOU!

Any questions?

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