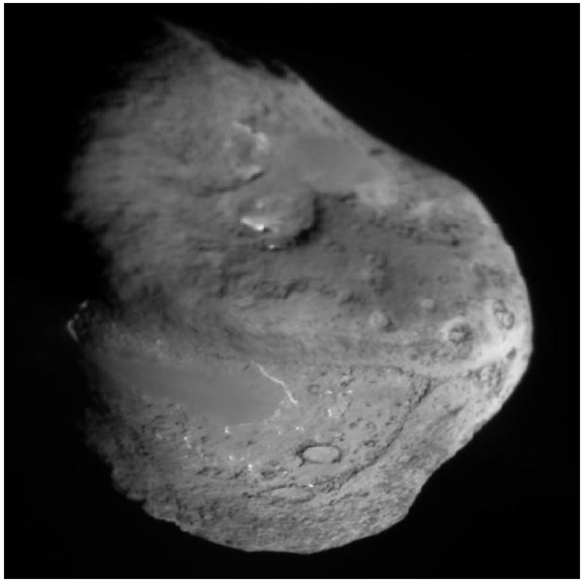
NASA's Near-Earth Object Program Overview

Don Yeomans/JPL

The Population of Near-Earth Objects is Made Up of Active Comets (1%) and Asteroids (99%)

Comets (Weak and very black icy dust balls)



•Weak collection of talcum-powder sized silicate dust

•About 30% ices (mostly water) just below surface dust

•Fairly recent resurfacing and few impact craters

•Some evidence that comet Tempel 1 does not have a uniform composition (i.e., more CO_2 in south)

Asteroids (run the gamut from wimpy ex-comet fluff balls to slabs of iron

•Most are shattered fragments of larger asteroids

- •Rubble rock piles - like Itokawa
- •Shattered (but coherent) rock - like Eros
- •Solid rock
- •Solid slabs of iron - like Meteor crater object

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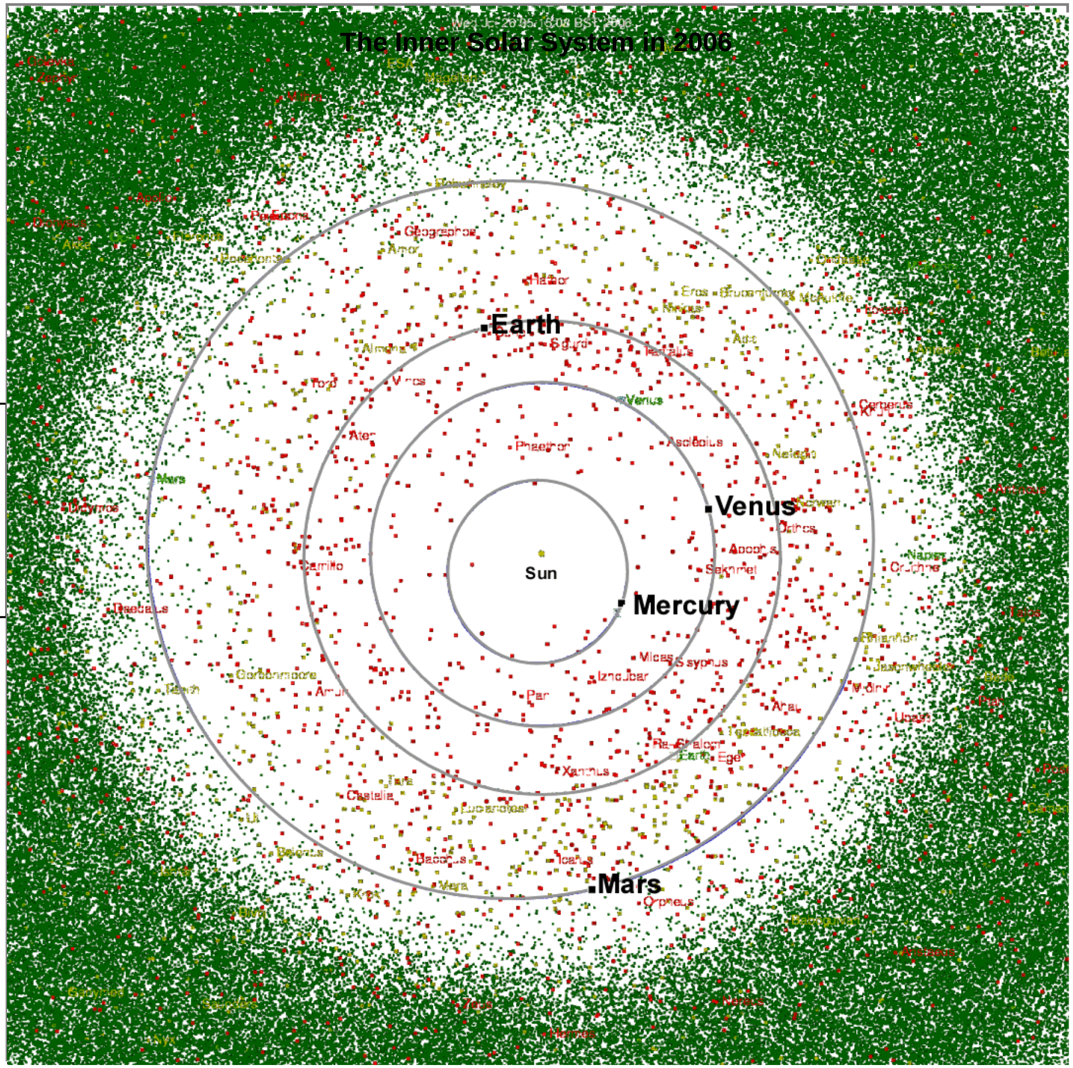
History of Known NEO Population

2010

Earth Crossing ●

Outside Earth's Orbit ●



Known
- 500,000 minor planets
- 7100 NEOs
- ~1100 PHOs

New Survey Will Likely Find
- 25,000+ NEOs (> 140m)
- 5,000+ PHOs

Scott Manley
Armagh Observatory

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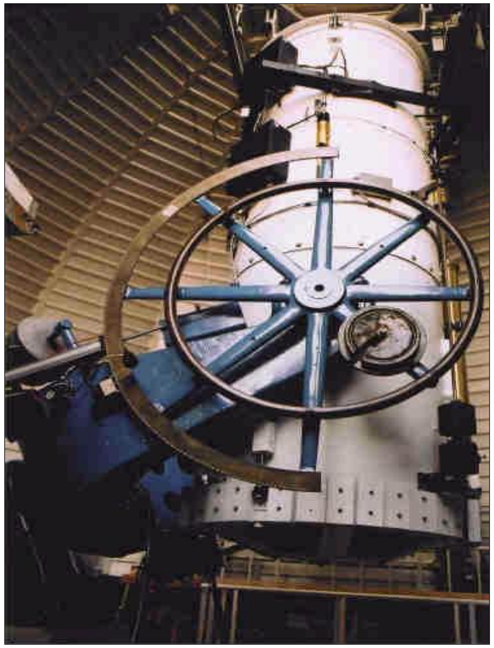
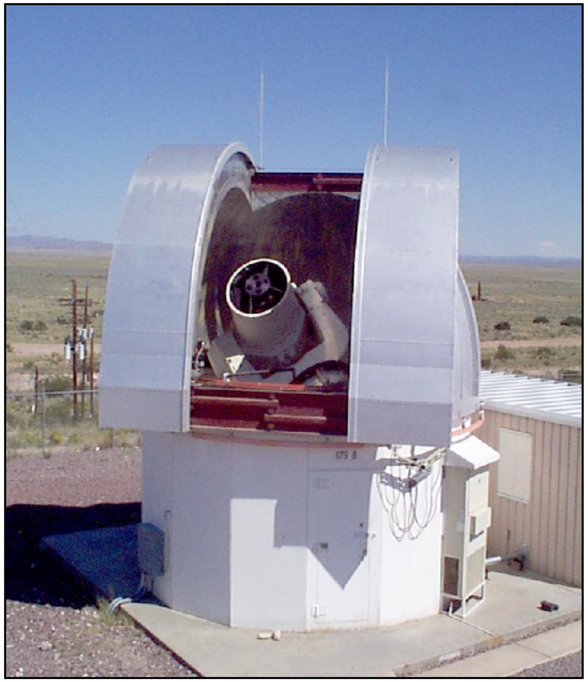
NASA's Current NEO Search Surveys



Spacewatch
Tucson, AZ

LINEAR, Socorro NM



NEO Program Office @ JPL
- Program coordination
- Automated SENTRY

http://neo.jpl.nasa.gov/

Minor Planet Center (MPC)
- IAU sanctioned
- Discovery Clearinghouse
- Initial Orbit Determination

NASA's NEO Observations Program run by Lindley Johnson (SMD)

Catalina Sky Survey
Tucson AZ & Australia

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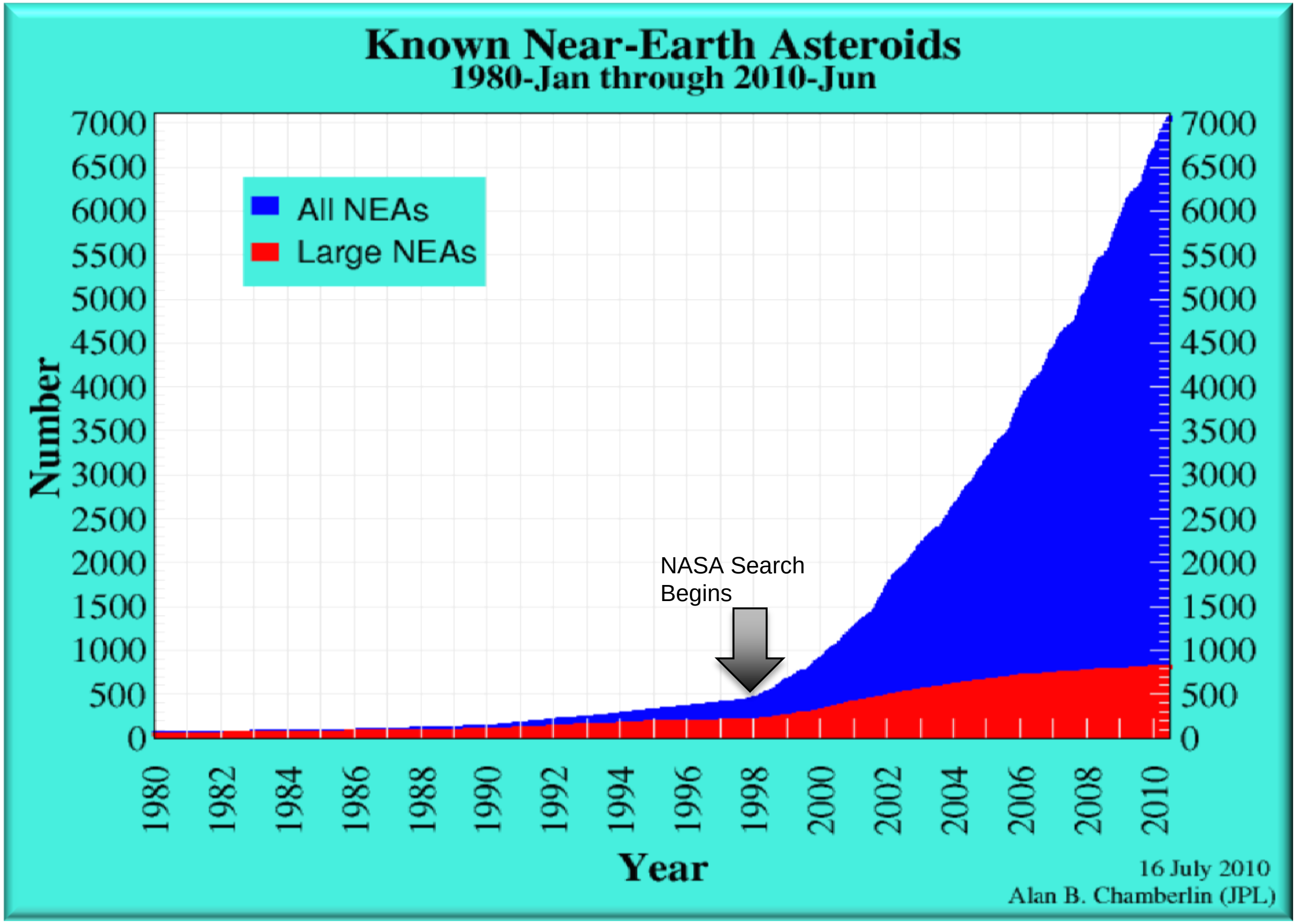
NASA NEO Survey Discoveries

NASA goal is to discover 90% of NEAs larger than 1 km. We've got >87% so far…

The next generation survey will have the goal of 90% of 140m+ objects



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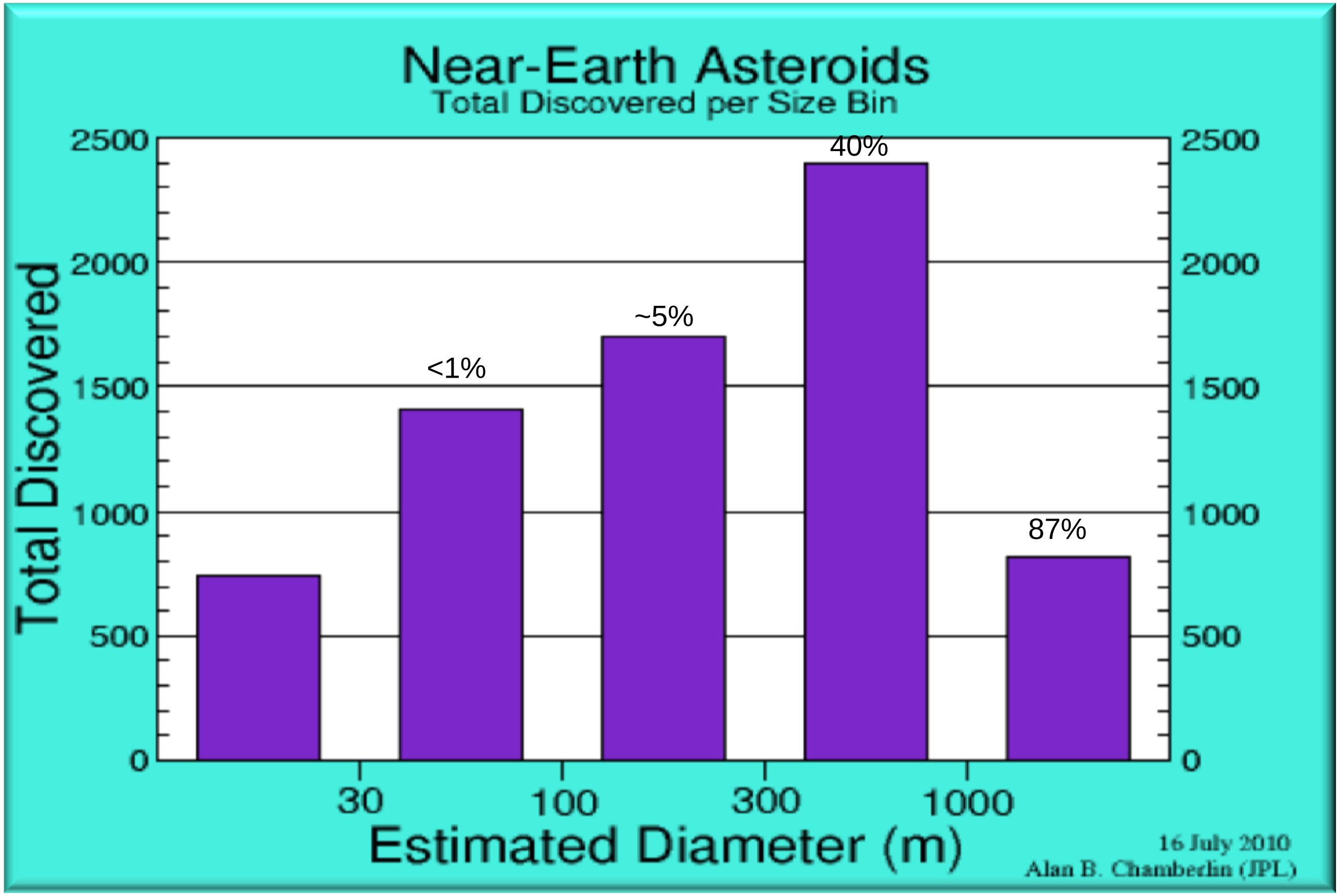
Less Than 1% of 30 meter sized NEOs Discovered to Date



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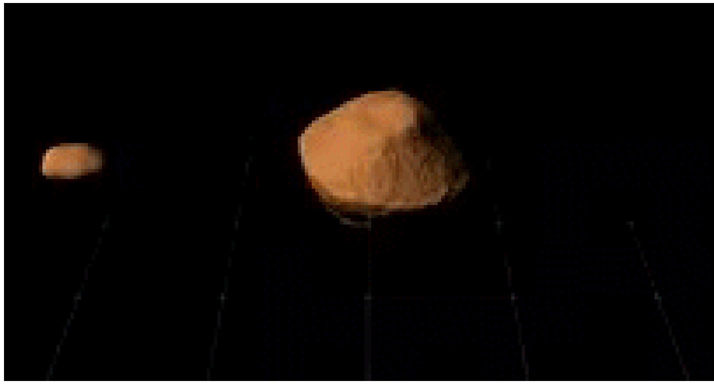
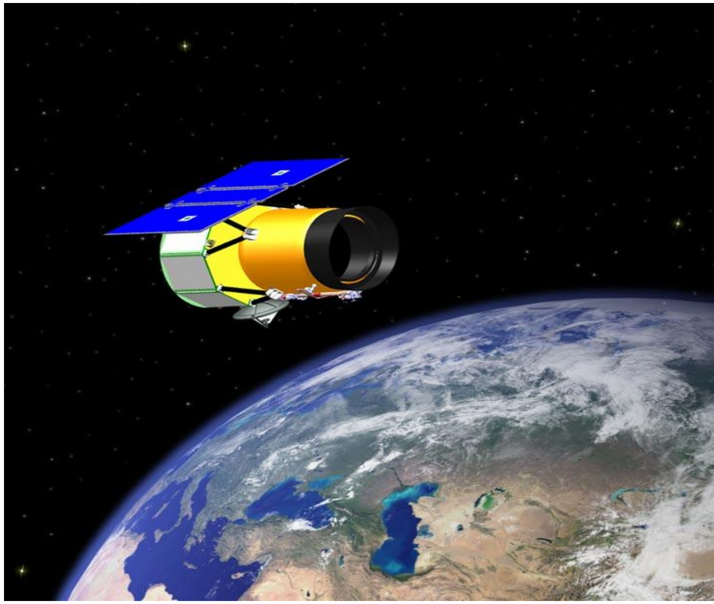
Radars and Satellite Observations Help Characterize NEOs

- ❑ Planetary Radars (Arecibo, Goldstone)
  - ❑ Provides dramatic improvements in the orbits & position predictions of NEOs
  - ❑ Often provides sizes, high resolution shapes, rotation states, roughness
  - ❑ Detects binaries & triple systems



Asteroid binary 1999 KW4

- ❑ Hubble (rough sizes/shapes, rotation rates, spectroscopy)
- ❑ Warm-Spitzer (characterization in two IR bands, spectra)
- ❑ WISE (NEO discoveries, size and albedo determinations, etc.)
- ➢ 104 NEAs and 15 comets to date



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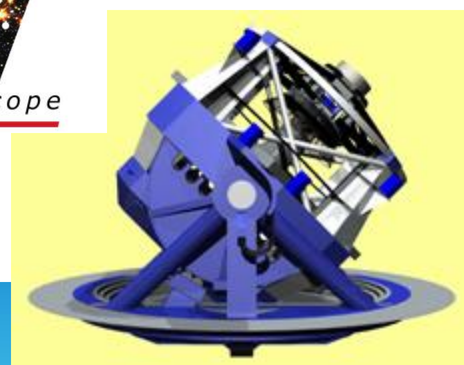
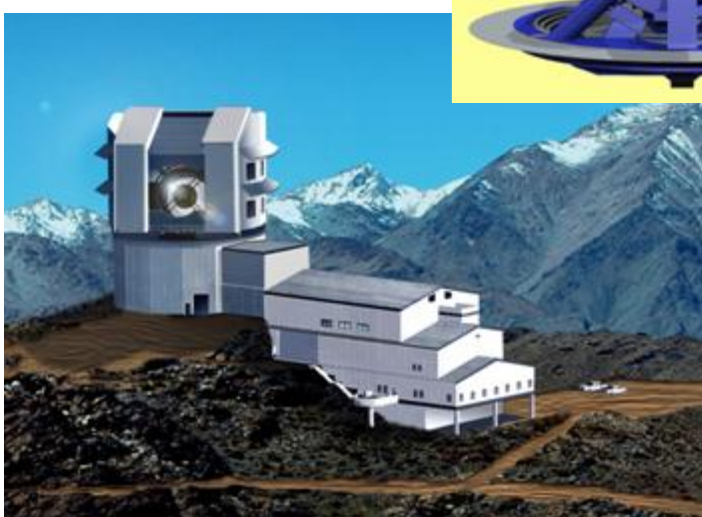
Next Generation Surveys

LSST
Large Synoptic Survey Telescope





Pan-STARRS
UNIVERSITY OF HAWAI'I

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Space-Based IR Telescope Would Be Extremely Efficient for Discovering NEOs.

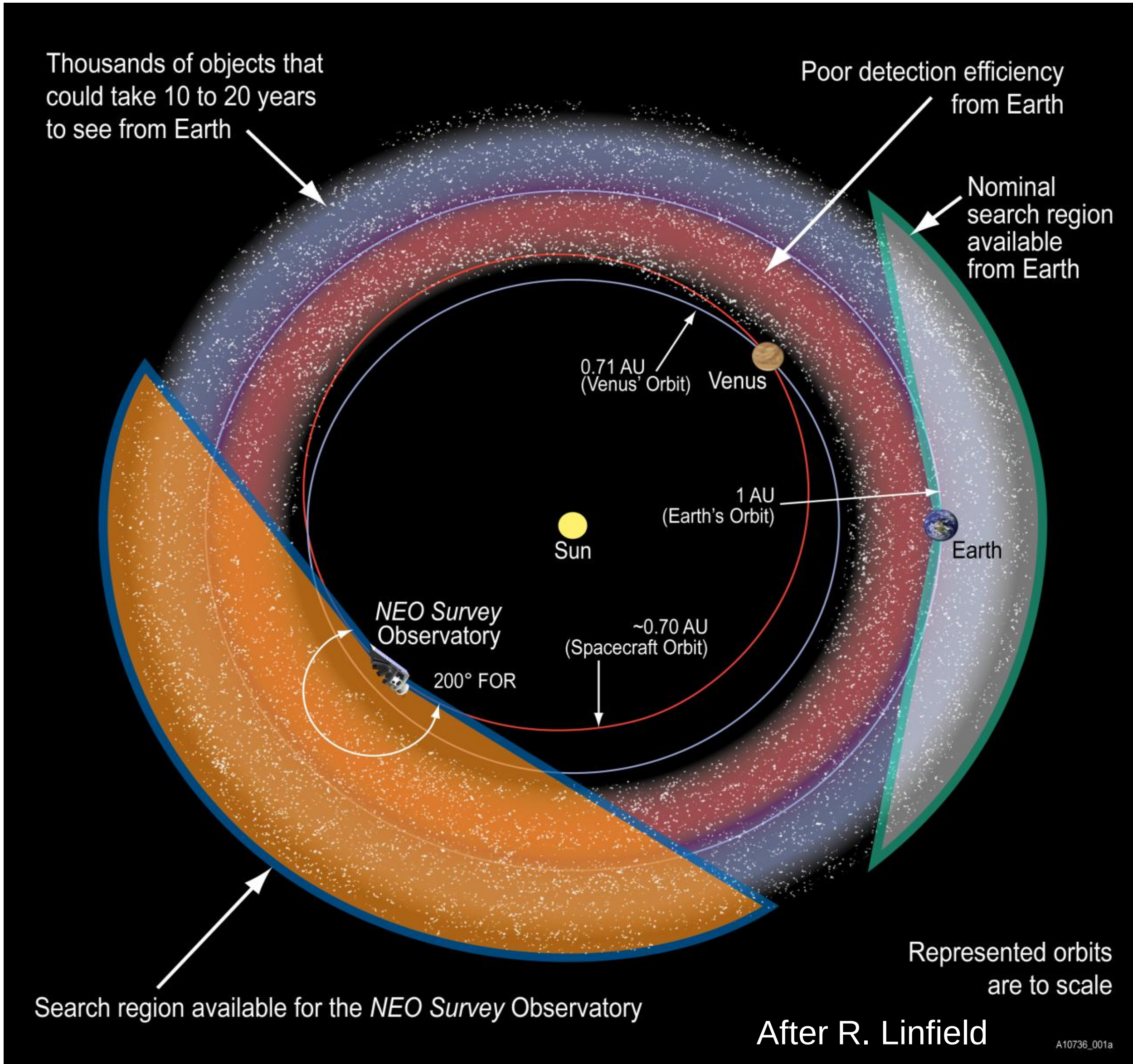
An IR telescope in a Venus-like orbit is far more efficient at finding NEOs:

•Better sky coverage because of geometry and issues relating to weather, background confusion, day/night, phase effects

• Most of energy emitted from NEOs is in mid-IR

•IR allows better NEO size determinations

•Space IR and ground-based visible telescopes are complementary



After R. Linfield

Space-Based IR Telescope(s)

Space-based IR is a more efficient discovery system.
2005: Congress asked NASA to find 90% of all NEOs > 140 meters by the end of 2020.

- Many decades – Using current ground-based optical telescopes
- 17-40 years - Next gen. optical surveys (Pan-STARRS/LSST)
- 6 years – 50 cm IR telescope in Venus-like orbit + Pan-STARRS
- 3 years – 2 IR telescopes phased 180 degrees apart

- 1 year – 60% completeness for human exploration NEO targets using 1 IR telescope. 90% completeness using 2 IR telescopes.

- IR telescope(s) in Venus-like orbits would dramatically improve catalog & hence warning times for the (most frequent) small impactors.

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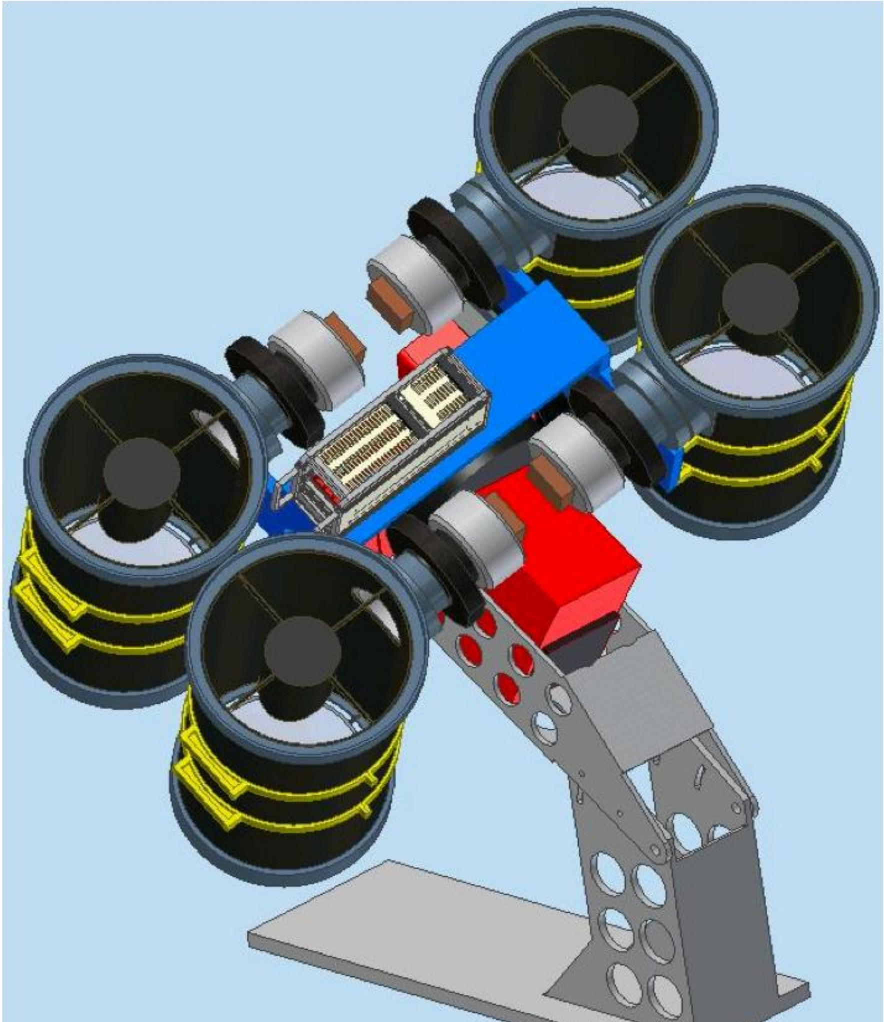
Proposed NEO Short Term Warning Systems (for civil defense – not mitigation)

Most likely damaging impactor will be ~ 30 meters in diameter. Average impact interval ~ 200 years but warnings will be more frequent.

Design a system for finding these small impactors days in advance of impact.

- Frequent sky coverage is all important
- One concept design would use 4 small, (25 cm) wide field of view (20 sq. deg.), off-the-shelf ("cheap") telescopes at 2 locations that are co-aligned in pairs.
- Observe the entire accessible sky (~20,000 sq. deg.) twice each night.
- Can provide several days or more warning for ~60% of objects on final approach.
    - ~ 1 week for 50 meter objects
    - ~ 3 weeks for 140 meter objects



After J. Tonry

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Communicating Risk
Lessons Learned

- ❑ Provide authoritative, verified & trusted results (NASA/JPL, Pisa)
- ❑ Explain orbit and risk determination procedures in simple terms
- ❑ Post verified results as soon as possible
- ❑ Continuously inform public

- ❑ Education process already underway

Neo.jpl.nasa.gov, ssd.jpl.nasa.gov

SENTRY, close approach data,
NEO discovery metrics, ephemerides,
risk assessment discussion

jpl.nasa.gov/Asteroidwatch)

Audio/video files, blog, FAQ,
Twitter, close approach widget,
missions, images, recent news

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NEO Program Benefits
Science

- Science: NEOs are the least changed remnants of the solar system formation process

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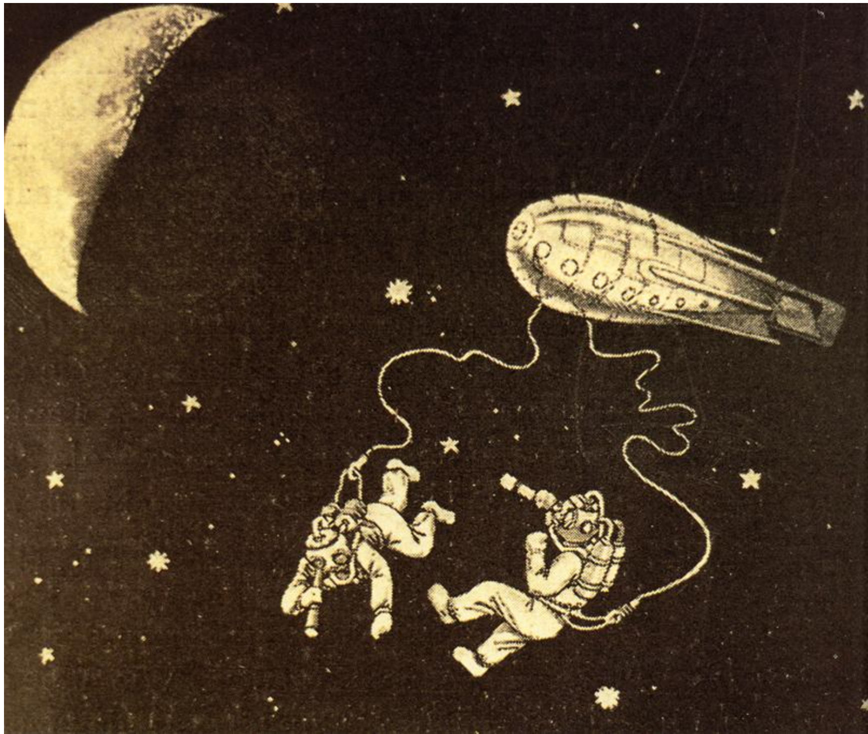
NEO Program Benefits
Space Resources

- Science: NEOs are the least changed remnants of the solar system formation process

- Space Resources: Future watering holes and fueling stations in space



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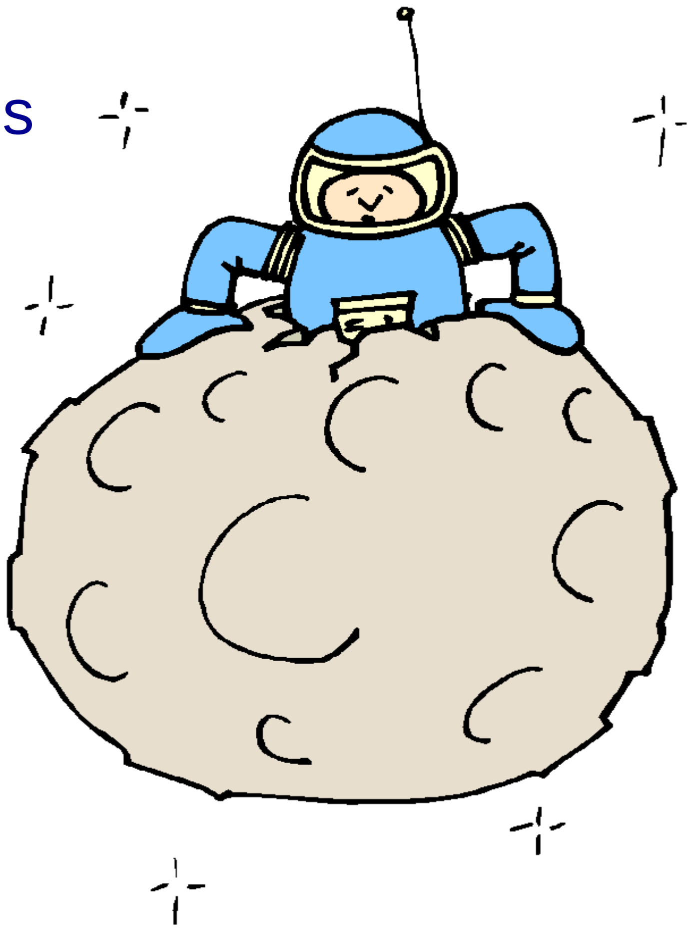
NEO Program Benefits
Human Exploration

- Science: NEOs are the least changed remnants of the solar system formation process

- Space Resources: Future watering holes and fueling stations in space

- Inform human exploration: What targets are available and what do we need to know before sending astronauts?



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NEO Program Benefits
Planetary Defense

- Science: NEOs are the least changed remnants of the solar system formation process

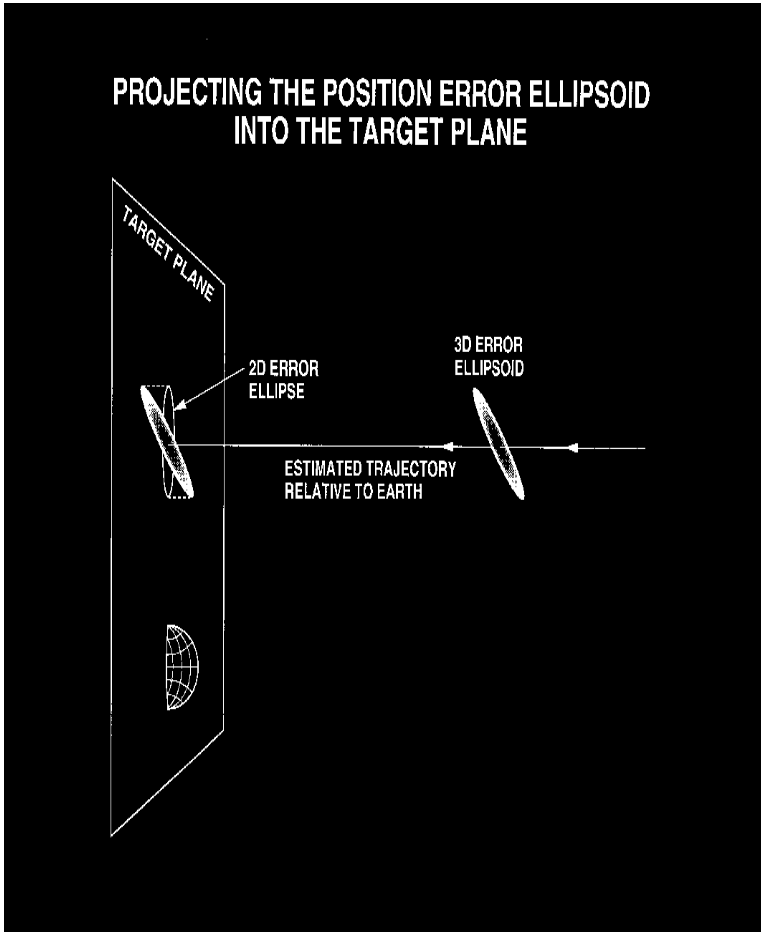
- Space Resources: Future watering holes and fueling stations in space

- Inform human exploration: What do we need to know before sending astronauts?

- Planetary Defense: We need to find them before they find us…

Computing and Verifying Impact Probabilities

- Quick look for future close Earth approaches with relatively high Impact Probability (IP). Output from automatic orbit update process.



- Robust IP determination useful for almost all Earth approaches. Used within on-line, automatic SENTRY system.

- Monte Carlo analysis - The last word for determining impact probabilities. Used to vet SENTRY.

JPL's SENTY NEO Risk Page

Current Impact Risks

http://neo.jpl.nasa.gov/risk/

JPL SSD NEO Sentry MPC NEODyS ADS MSNBC Wikipedia seatguru SBDB Query SBDB Search SBDB Help Apple News (1230) Inside JPL

Sentry

Recently Observed Objects
(within past 60 days)

Object Designation	Year Range	Potential Impacts	Impact Prob. (cum.)	$V_{infinity}$ (km/s)	H (mag)	Est. Diam. (km)	Palermo Scale (cum.)	Palermo Scale (max.)	Torino Scale (max.)
2010 KH	2018-2077	29	1.4e-08	9.79	18.8	0.593	-4.59	-5.11	0
2010 JC170	2021-2109	148	5.3e-07	4.25	22.1	0.130	-4.76	-5.56	0
2010 MY112	2018-2107	34	3.2e-08	23.82	20.7	0.250	-4.80	-5.35	0
2010 LV108	2033-2108	17	7.0e-07	9.28	22.4	0.111	-4.88	-5.17	0

For each object listed, we provide the following up-to-date data:

- Year or interval of potential impacts and number of impact possibilities
- Cumulative impact probability (IP)
- Collision velocity & estimated diameter
- Torino Scale (depends upon impact energy and impact probability)
  - Defined only over next 100 years; A value = 1 "merits careful attention" and is colored green. Scale runs from 0 (white) – 10 (red)
- Palermo Scale (depends upon impact energy, IP & impact proximity)
  - A Palermo Scale value > 0 is above the "background" level

Objects Not Recently Observed

Object Designation	Year Range	Potential Impacts	Impact Prob. (cum.)	$V_{infinity}$ (km/s)	H (mag)	Est. Diam. (km)	Palermo Scale (cum.)	Palermo Scale (max.)	Torino Scale (max.)
101955 1999 RQ36	2169-2199	8	7.1e-04	6.36	20.7	0.560	-1.12	-1.52	n/a
2007 VK184	2048-2057	4	3.4e-04	15.63	22.0	0.130	-1.82	-1.83	1

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Backup Slides

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Introduction to NEOs

- "Near Earth Objects (NEOs)"- any comet or asteroid passing within ~ 45 million km of Earth's orbit
- "Potentially Hazardous Objects" – Subset of NEOs larger than ~ 140 meters that can pass within 7.5 million km of Earth's orbit (about 20% of NEO population)
- NEOs are of great importance to humankind
  - Planetary Science: NEOs offer clues to the chemical mix and environment during the early solar system formation process.
  - Life Sciences: NEOs likely provided much of the water and organics to the early Earth – thus allowing life to form.
  - Subsequent NEO impacts punctuated evolutionary process allowing only the most adaptable species to continue (i.e. including mammals).
  - Space Resources: Could provide future raw materials for human exploration (i.e., H_20, O_2, rocket fuel, metals).
  - Planetary Defense: We need to find them before they find us!
  - S/C landings & returns: NEOs are among the most accessible objects.
  - Space-based IR and the next generation of ground-based optical surveys need to be carried out to supply suitable mission targets and meet the 12/30/2005 Congressional directive to find 90% of the NEO population larger than 140 meters.

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Communicating NEO Risk is Difficult

- ❑ Impact probability computations are complex and arcane.
- ❑ Serious impact events are low probability/high consequence.
- ❑ Vast majority of actual impact events will be small NEAs:
  - ❑ Bolides and fireballs take us by surprise.
  - ❑ Small NEAs are often found after they pass Earth closely.
  - ❑ Without much larger, wide-field telescope apertures, warnings times will be short or non-existent.
- ❑ Long-term non-zero impact predictions (IP ≠ 0) can be followed by a rapid drop to IP = 0 when sufficient data are available.
  - ❑ Sometimes leads to charges that NASA made a mistake or there is a conspiracy to withhold news of upcoming disaster.

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Rapidly Reducing NEO Position Uncertainties – Apophis Example