Potentially Hazardous Asteroid Workshop

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United States Government Policy and Approach Regarding Planetary Defense

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May 2011

Source

US Office of Science and Technology Policy (OSTP)
Letter to Congress dated 15 October, 2010*

Response to Section 804 of NASA Authorization Act of 2008

The Director of OSTP will:

(1) develop a policy for notifying Federal agencies and relevant emergency response institutions of an impending near-Earth object threat, if near-term public safety is at risk; and

(2) recommend a Federal agency or agencies to be responsible for –

(A) protecting the United States from a near-Earth object that is expected to collide with Earth; and

(B) implementing a deflection campaign, in consultation with international bodies, should one be necessary

* http://www.whitehouse.gov/sites/default/files/microsites/ostp/ostp-letter-neo-senate.pdf

NASA Authorization Act of 2008

Title VIII – Near Earth Objects Signed Oct 2008

- ***SEC. 803. REQUESTS FOR INFORMATION.***
- *The Administrator shall issue requests for information on--*
- *(1) a low-cost space mission with the purpose of rendezvousing with, attaching a tracking device, and characterizing the Apophis asteroid; and*
- *(2) a medium-sized space mission with the purpose of detecting near-Earth objects equal to or greater than 140 meters in diameter.*
- ***SEC. 804. ESTABLISHMENT OF POLICY WITH RESPECT TO THREATS POSED BY NEAR-EARTH OBJECTS.***
- *Within 2 years after the date of enactment of this Act, the Director of the OSTP shall--*
- *(1) develop a policy for notifying Federal agencies and relevant emergency response institutions of an impending near-Earth object threat, if near-term public safety is at risk; and*
- *(2) recommend a Federal agency or agencies to be responsible for--*
- *(A) protecting the United States from a near-Earth object that is expected to collide with Earth; and*
- *(B) implementing a deflection campaign, in consultation with international bodies, should one be necessary.*
- ***SEC. 805. PLANETARY RADAR CAPABILITY.***
- *The Administrator shall maintain a planetary radar that is comparable to the capability provided through the Deep Space Network Goldstone facility of NASA.*
- ***SEC. 806. ARECIBO OBSERVATORY.***
- *Congress reiterates its support for the use of the Arecibo Observatory for NASA-funded near-Earth object-related activities. The Administrator, using funds authorized in section 101(a)(1)(B), shall ensure the availability of the Arecibo Observatory's planetary radar to support these activities until the National Academies' review of NASA's approach for the survey and deflection of near-Earth objects, including a determination of the role of Arecibo, that was directed to be undertaken by the Fiscal Year 2008 Omnibus Appropriations Act, is completed.*
- ***SEC. 807. INTERNATIONAL RESOURCES.***
- *It is the sense of Congress that, since an estimated 25,000 asteroids of concern have yet to be discovered and monitored, the United States should seek to obtain commitments for cooperation from other nations with significant resources for contributing to a thorough and timely search for such objects and an identification of their characteristics.*

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Background

- US National Space Policy, June 28, 2010*

NASA shall: "Pursue capabilities, in cooperation with other departments, agencies, and commercial partners, to detect, track, catalog, and characterize near-Earth objects to reduce the risk of harm to humans from an unexpected impact on our planet and to identify potentially resource-rich planetary objects."

* http://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf

- US President's FY2012 NASA Budget Request:

"The expanded Near-Earth Orbit Observation (NEOO) program [$20.4M] will improve and increase its efforts to detect Earth approaching asteroids and comets that may provide resources for our exploration of the inner solar system, or could become potential impact hazards to the Earth. It will also expand efforts to characterize their nature, both to better understand their composition and provide information for study of potential hazard mitigation techniques."

- US President's new plan for human space flight, announced April 15, 2010*, establishes the goal of conducting a human mission to an NEO by 2025

* http://www.whitehouse.gov/the-press-office/remarks-president-space-exploration-21st-century

NEO Threat Detection

Within US Government:

- NASA will coordinate NEO detection and threat information from all organizations within the NEO observation community
- NASA has instituted communications procedures, including direction with regard to public release of information
- NASA notification procedures are set into motion only after the necessary observations, analyses, and characterization efforts have taken place to determine that a space object indeed represents a credible threat
  - Depends on level of risk and urgency, may unfold for years after detection
  - Will entail various combinations of:
    - Increased monitoring
    - Cross-checks of potentially hazardous trajectories as needed
    - Accelerated observations and orbit determination if potential hazard is near term

NEO Threat Notification

Upon notification from NASA:

Of impending NEO Threat to United States territory:

- The Federal Emergency Management Agency (FEMA) takes lead to notify appropriate Federal, state and local authorities and emergency response institutions utilizing existing resources and mechanisms
  - When time/location of affected areas known, activate National Warning System
  - Analogous to large re-entering space debris and/or hurricane warning procedures
  - Post-impact event, analogous to other disaster emergency and relief efforts

Of NEO Threat beyond United States territory:

- Recognizing vital role US efforts lead in NEO detection activities, US Department of State facilitates international notifications in effort to minimize loss of human life and property
  - Bilaterally through diplomatic channels to potentially affected countries
  - To member nations of multilateral forums – UN entities (OOSA, COPUOS), NATO, etc
  - Post-impact event, convey offers of disaster relief and technical assistance

Potential NEO Mitigation/Deflection

- Essential first step is continued enhancement of efforts to detect NEOs
  - Identify potential impact hazards early
  - Provide as much advanced warning of impact threat to enable more mitigation options
- Potential roles and responsibilities for mitigation options is in early stage of development and not yet ready for implementation
  - Wide range of possible scenarios and challenges involved
  - Significantly more analysis and simulation needed to understand feasibility and effectiveness of several approaches, and technical assessment of current technologies
- NASA to take lead to conduct foundational analysis and simulation, assessment of applicable technologies
  - Close coordination with DOD, FEMA, and other relevant departments and agencies
  - Possible emergency response exercises to be led by FEMA
  - Outreach to relevant private-sector stakeholders to leverage related work
  - Important to engage other nations and multilateral forums to explore opportunities for international cooperation, e.g. UNCOPUOS, European Union, ISECG

NEO Observation Program

US component to International Spaceguard Survey effort

Has provided 99% of new detections of NEOs

Began with NASA commitment to House Committee on Science in May, 1998

- Averaged ~$4M/year Research funding 2002-2010
- 400% plus-up to $20.4M in 2012 authorized budget

Scientific Objective: Discover 90% of PHOs larger than 140 meters in size by end of 2020 and characterize sample

Currently has 29 ongoing projects to:

– Detect and Track	3+1
– Follow-Up	5
– Characterize	9
– Process and Manage	3
– Study techniques and improvements	5
– Study techniques for mitigation	3

NASA's NEO Search Program

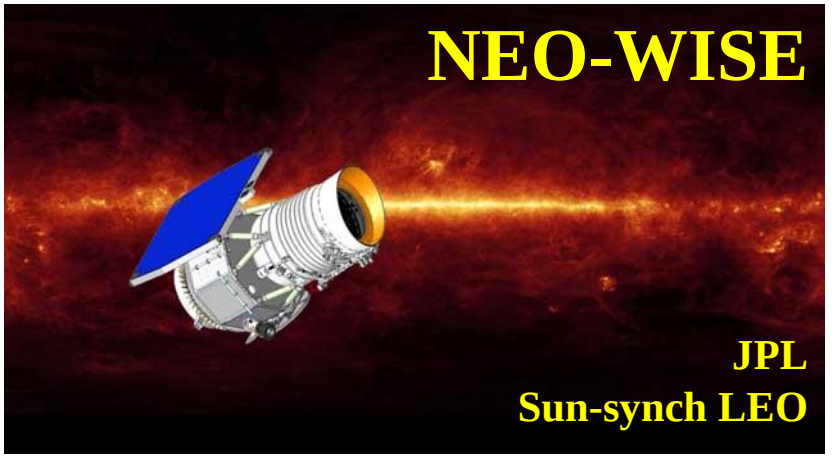
(Current Systems)

Minor Planet Center (MPC)
- IAU sanctioned
- Int'l observation database
- Initial orbit determination

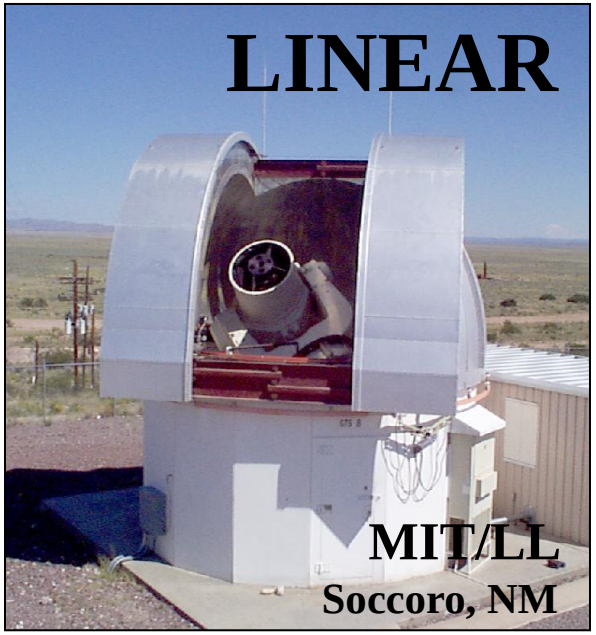
www.cfa.harvard.edu/iau/mpc.html

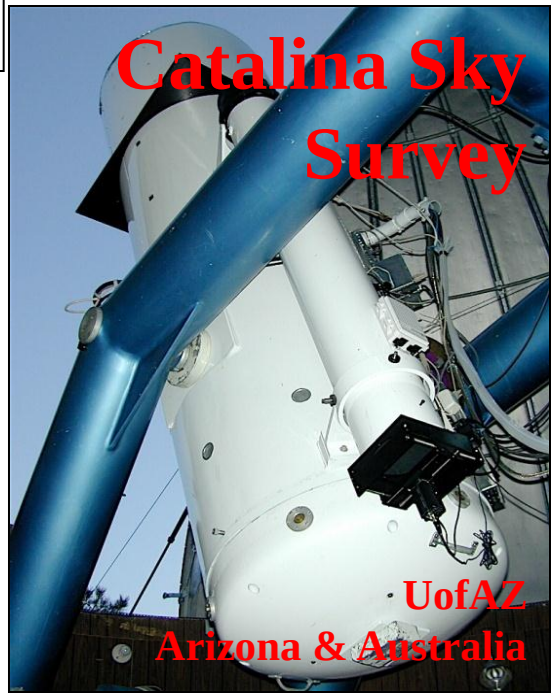
NEO Program Office @ JPL
- Program coordination
- Precision orbit determination
- Automated SENTRY

www.neo.jpl.nasa.gov

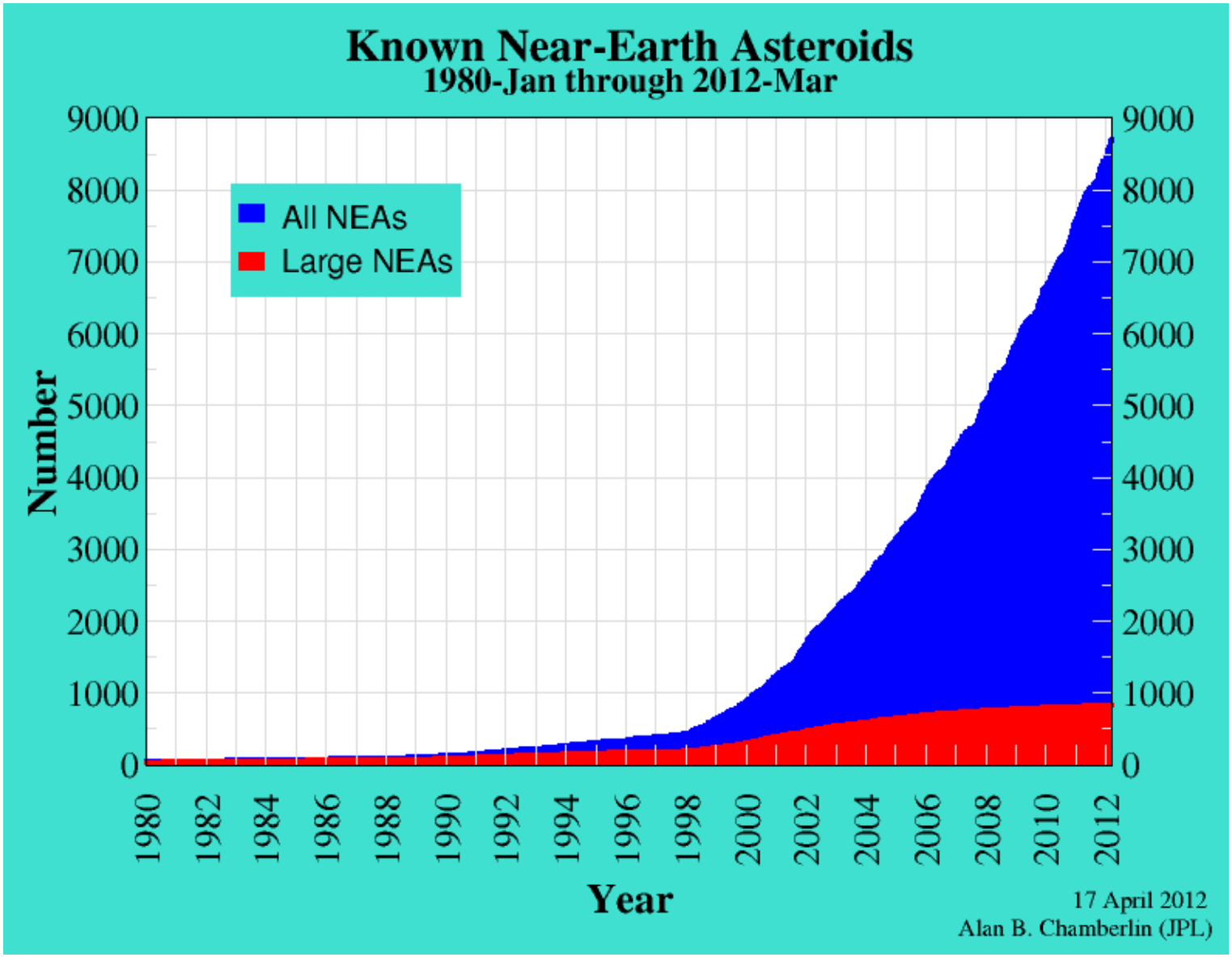


End of Operations Feb 2011, Analysis Of Data Continues





Known Near Earth Asteroid Population



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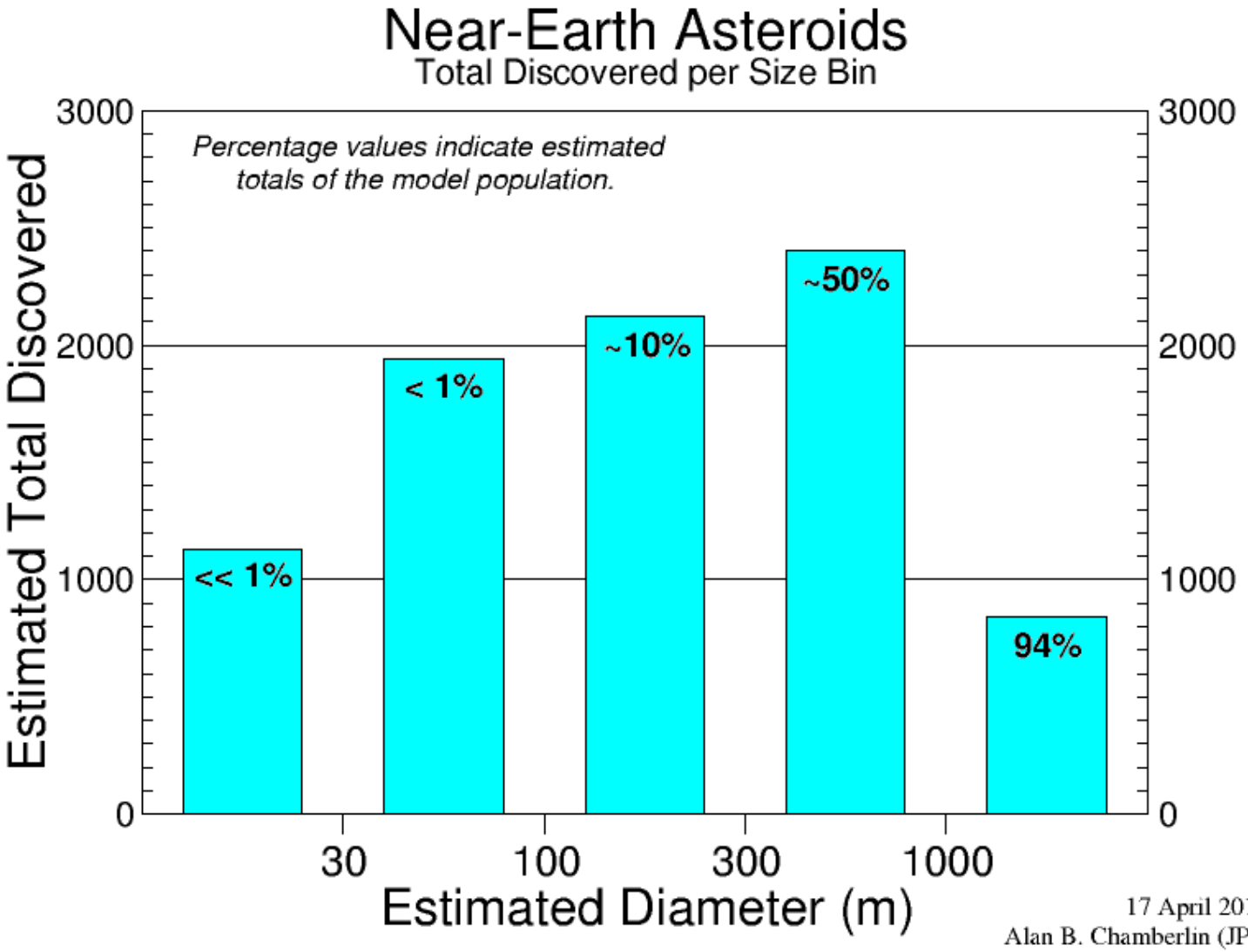
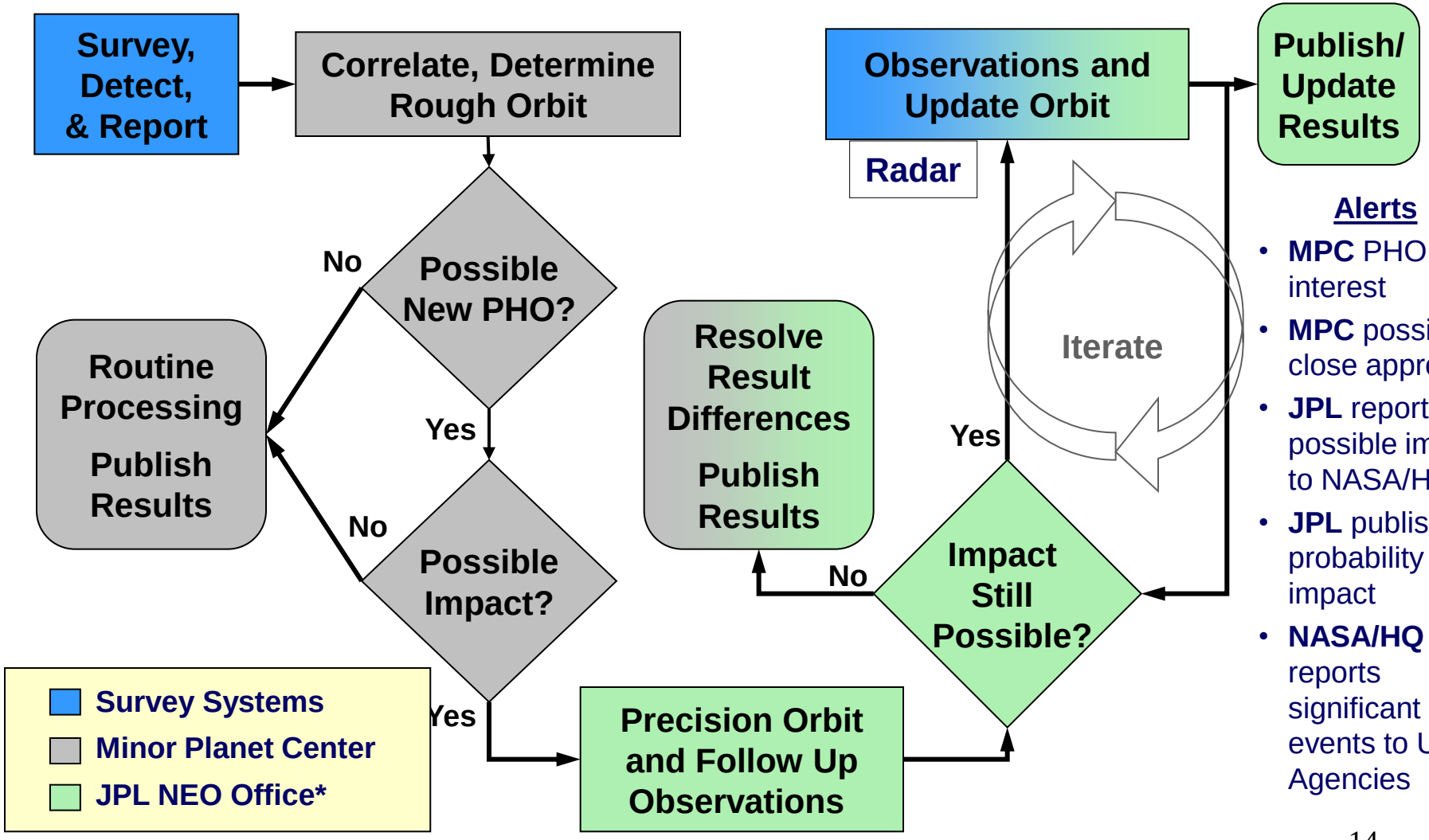


Spaceguard Survey Catalog Program

Current Spaceguard Survey Infrastructure and Process



Alerts

- **MPC** PHO of interest
- **MPC** possible close approach
- **JPL** reports possible impact to NASA/HQ
- **JPL** publishes probability of impact
- **NASA/HQ** reports significant events to USG Agencies

* In parallel with NEODyS

Funded Follow-Up Assets

- Astronomical Research Institute
  - Coordination of amateurs and students worldwide
- Spacewatch
  - Dropped from survey ops, but still finds a few
- Magdalena Ridge Observatory
  - 2.4 m telescope, extremely capable observers
- Table Mountain Observatory
  - 0.6 m telescope, limited use
- Dave Tholen – “master astrometer”
  - Can Use MKO UH 80”, CFHT 3.6 m, Subaru and Keck

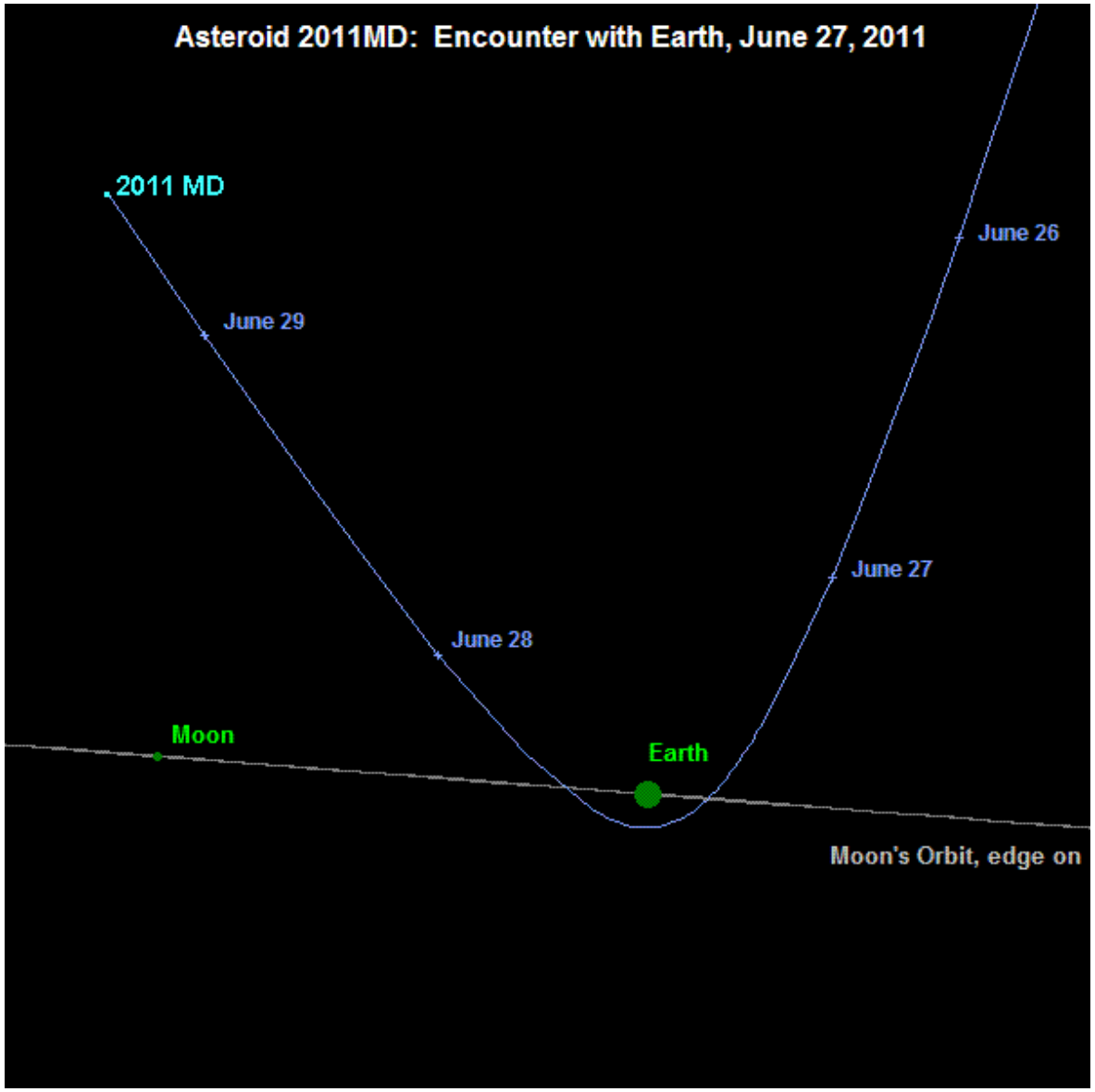
Close Approaching Asteroids in 2011

Object	Closest Approach Date -Time	Min Dist. x Lunar	Relative Velocity (km/sec)	H Mag(v)	Size meters (est)
2011 CQ1	2011-Feb-04 19:38	0.03	9.69	32.0	1
2011 MD	2011-Jun-27 17:00	**0.05**	6.70	28.1	14
2011 CF22	2011-Feb-06 11:39	0.1	19.60	30.9	3
2011 GP28	2011-Apr-06 19:39	0.2	14.80	29.4	6
2011 TO	2011-Sep-28 15:25	0.3	8.87	26.3	32
2011 BW11	2011-Jan-25 06:33	0.3	23.95	28.3	12
2011 EY11	2011-Mar-07 03:26	0.3	11.86	28.6	10
2011 YC40	2011-Dec-28 02:29	0.3	11.36	29.7	5
2011 AM37	2011-Jan-11 11:46	0.3	4.41	29.7	5
2011 CA7	2011-Feb-09 19:27	0.3	9.33	30.3	4
2011 OD18	2011-Jul-28 08:38	0.4	9.54	26.5	30
2011 UX255	2011-Oct-28 17:42	0.4	26.96	27.4	21
2011 GW9	2011-Apr-06 04:53	0.5	11.36	28.1	14
2011 UT	2011-Oct-12 19:14	0.6	10.17	25.8	40
2011 CA4	2011-Jan-31 04:08	0.6	6.00	27.0	24
2011 SE58	2011-Sep-27 02:46	0.6	15.85	27.6	19

Object	Closest Approach Date -Time	Min Dist. x Lunar	Relative Velocity (km/sec)	H Mag(v)	Size meters (est)
2011 EN11	2011-Mar-03 08:47	0.6	11.21	27.9	16
2011 EM40	2011-Mar-08 04:05	0.6	10.79	28.0	15
2011 YC63	2011-Dec-30 02:16	0.6	18.80	29.0	8
2011 DU9	2011-Feb-23 19:03	0.7	8.92	26.7	28
2011 UL169	2011-Oct-26 02:31	0.7	9.54	28.3	12
2012 AQ	2011-Dec-29 08:32	0.7	3.28	30.7	3
2005 YU55	2011-Nov-08 23:28	0.8	13.72	21.1	**380**
2011 SM173	2011-Sep-30 17:02	0.8	12.71	27.8	17
2011 AN52	2011-Jan-17 23:19	0.8	15.92	28.5	11
2011 XC2	2011-Dec-03 15:20	0.9	20.93	23.0	150
2011 PU1	2011-Jul-24 19:27	0.9	5.60	25.1	60
2011 EB74	2011-Mar-16 21:54	0.9	7.71	26.9	25
2011 BY10	2011-Jan-20 08:29	0.9	7.84	27.3	22
2009 BD	2011-Jun-02 00:51	0.9	1.91	28.3	12
2009 TM8	2011-Oct-17 11:09	0.9	8.18	28.6	10
2011 JV10	2011-May-05 17:13	0.9	5.33	29.7	5
2011 YQ1	2011-Dec-14 14:19	1.0	11.79	25.6	50

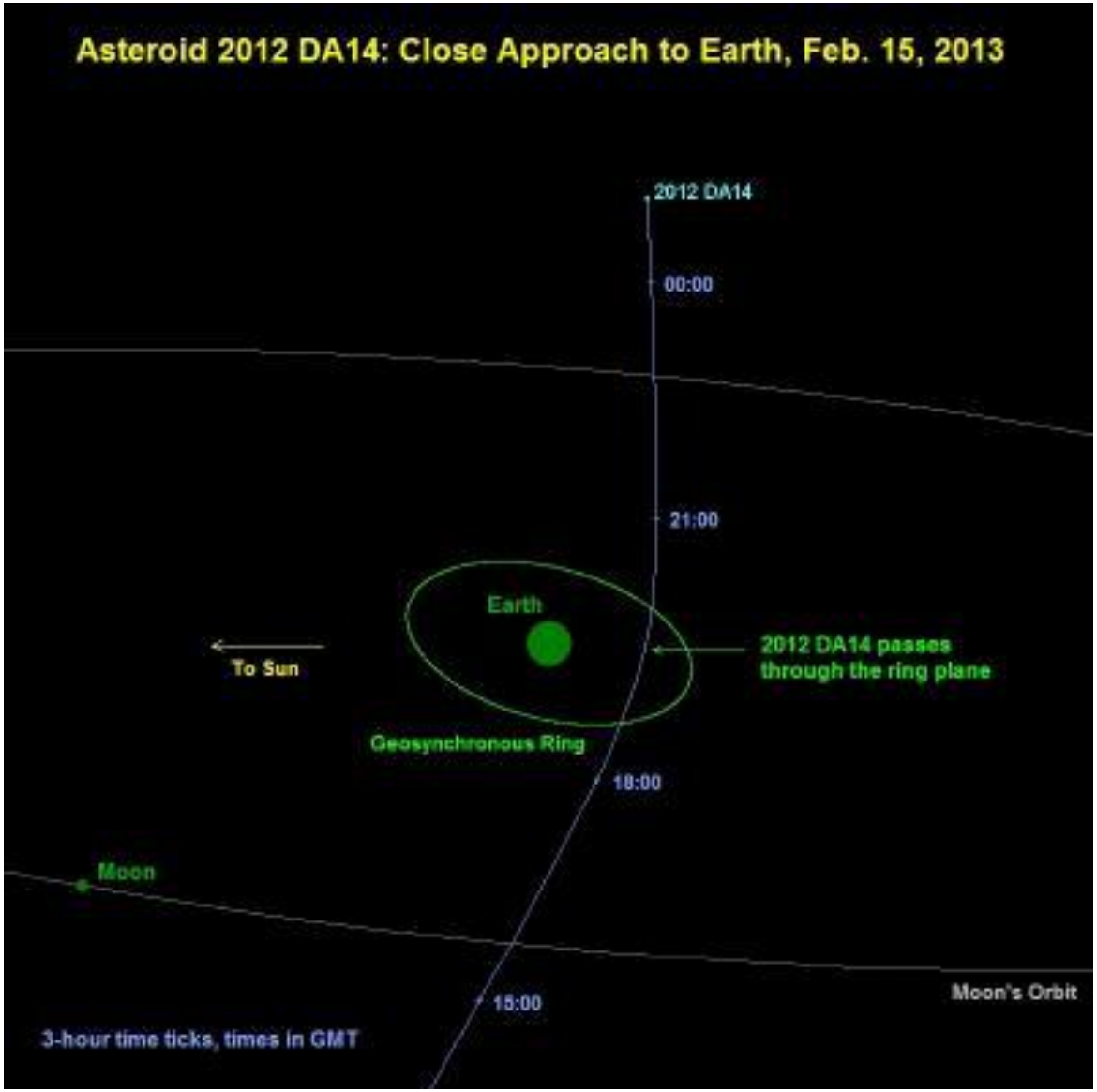
Close Approach of Asteroid 2011 MD

Asteroid 2011 MD passed only 12,300 kms (7,600 miles) above the Earth's surface on Monday June 27. The NEO was discovered by NASA's LINEAR asteroid search team observing from Socorro, New Mexico. The diagram to the right gives a view looking from the general direction of the Sun that indicates that 2011 MD reached its closest Earth approach point in extreme southern latitudes - in fact over the southern Atlantic Ocean.



2012 DA14 to Approach Earth Feb 15, 2013

Asteroid 2012 DA14 will pass within about 3.5 Earth radii of the Earth's surface on February 15, 2013. Although its size is not well determined, this near-Earth asteroid is thought to be about 45 meters in diameter. Asteroid 2012 DA14 will pass inside the Earth's geosynchronous orbit ring, located about 35,800 kilometers above the equator



Funded Characterization Assets

- Infra-Red Telescope Facility
  - Principle Investigators
    - Rick Binzel
    - Mike Gaffey
- Planetary Radars
  - Goldstone Solar System Radar
  - Arecibo Radar
    - Principle Investigators
      - Lance Benner
      - Mike Nolan

Radar Studies of NEOs

Observations on the limited accessible objects

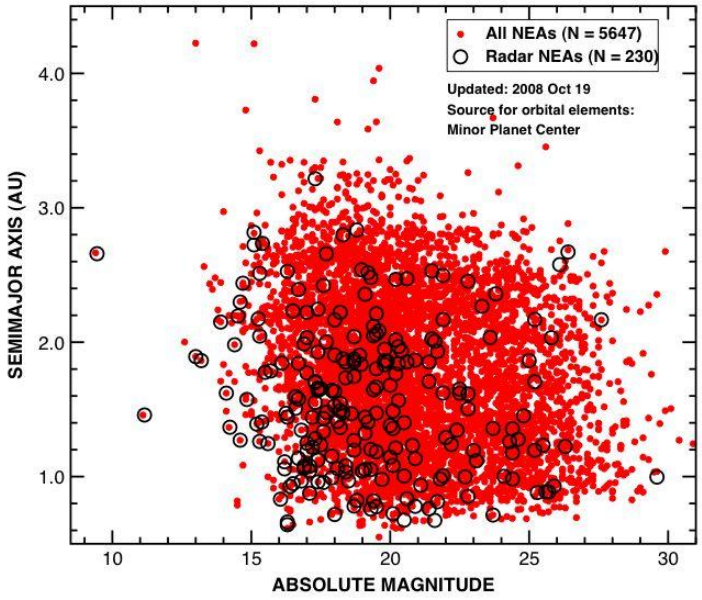
– Within 20 million miles, 5 million miles for imaging

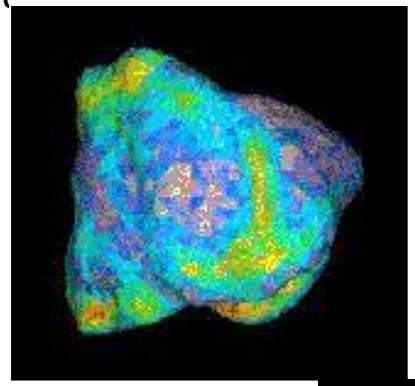
– 20 to 30 NEOs/year from Goldstone and Arecibo

– Required for timely precision orbit determination

– Characterization with sufficient signal strength

- Shape, spin-state, surface structure
- Satellites (an then derived mass)

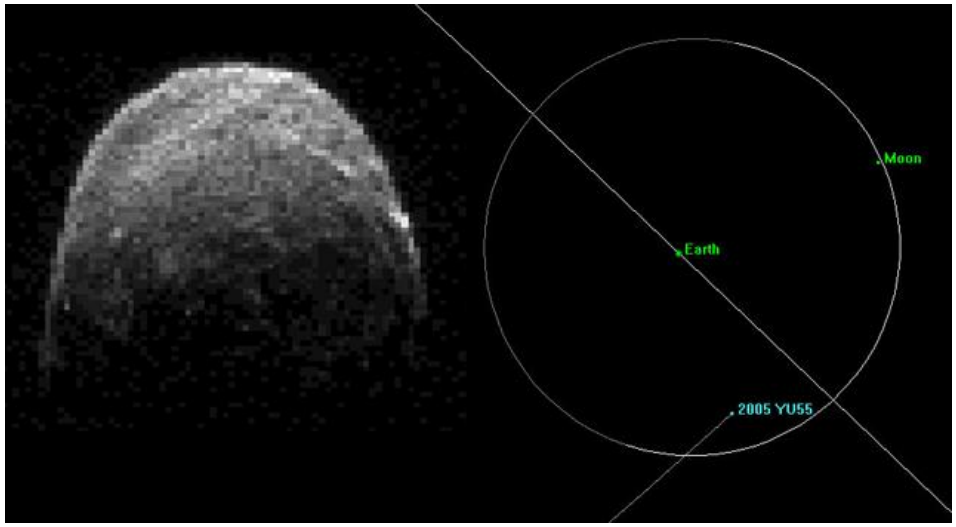




Shape, Size of 6489 Golevka

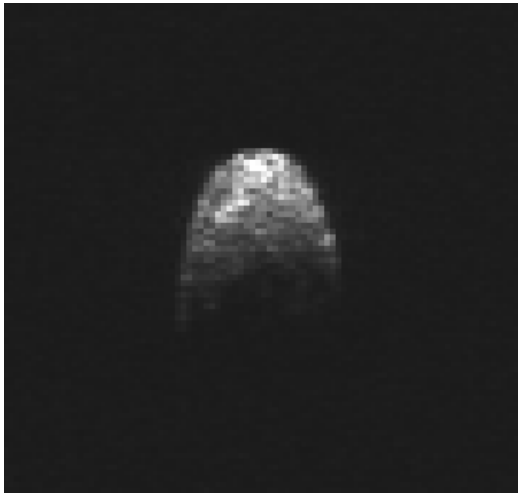
Study of Shape, Size, Motion and Mass of 66391 (1999 KW4)

Pass of Asteroid 2005 YU55 Observed with Ground-based Radars



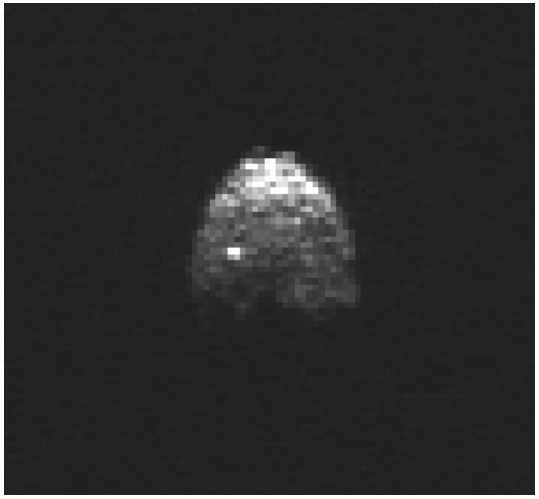
This image of asteroid 2005 YU55 with about 12 foot resolution was obtained by Lance Benner at NASA's Goldstone Radar on Nov. 7, 2011, about one day before closest approach, when the object was at 3.6 lunar distances, which is about 860,000 miles from Earth. NASA/JPL-Caltech

- 2005 YU55 passed by Earth the evening of 8 Nov, 2 at just less than 200,000 miles – within the Moon's orbit
- Earth based planetary radars at Goldstone, CA and Arecibo, PR, were used to track and image the asteroid
- Planetary radar can be used to determine the size and shape of the asteroid, study its surface properties, and help predict any future encounters with the Earth
- The radar imaging shows the asteroid to be roughly spherical, about 1300 feet across, and rotating with a period of about 18 hours
- This event demonstrates how Near Earth Asteroids could be characterized by planetary radar for studies of potential human spaceflight destinations

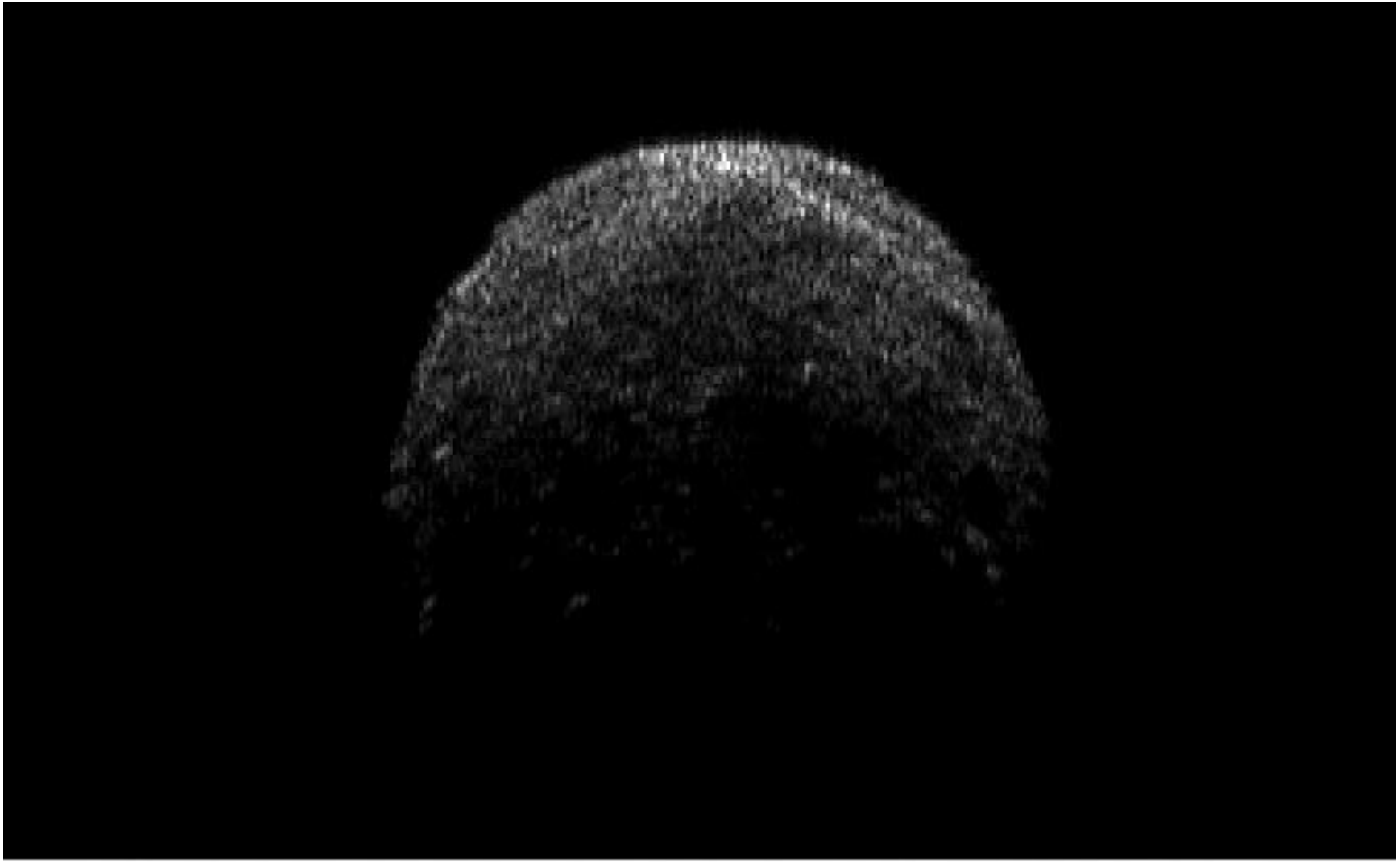


These two radar images were obtained by Patrick Taylor at the Arecibo Planetary Radar on Nov 12. The asteroid was about 2,000,000 miles away and the images show objects of about 25 feet in size. The image on right shows a radar bright feature, possibly a boulder on the asteroid's surface.

The Arecibo Observatory is operated by SRI International under a cooperative agreement with the National Science Foundation, in alliance with Ana G. Méndez-Universidad Metropolitana, and the Universities Space Research Association. The radar operations are funded by NASA.



Radar Rotation Study of 2005 YU55

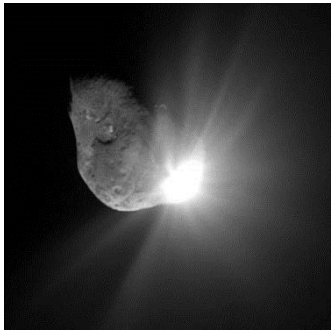


What Could We Do About It?

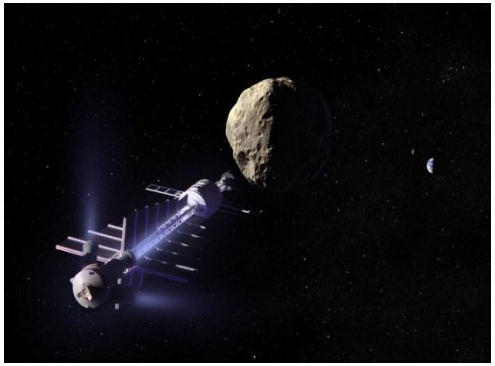
Planetary Defense - Mitigating an Impact Event

- At the very least, "civil defense"
  - Days to weeks warning, evacuate area to be affected
- Technology exists to provide years to decades warning
  - Change the hazardous object's orbit trajectory
  - But will need to find them as early as possible
- With Sufficient warning, 3 methods of Orbit Deflection

1. Kinetic Impactor - instant push



2. Gravity Tractor - slow pull



3. Nuclear device - surface material blow-off

Funded Mitigation Related Studies

- Keith Holsapple – University of Washington
  - Comprehensive Studies of Two Mitigation Technologies for Threatening Asteroids: Impacts and Explosions
- Dan Scheeres – University of Colorado, Boulder
  - Response of Rubble Pile Asteroids to Energetic Events
- Erik Asphaug – Univ. Cal., Santa Cruz
  - Sensitivity of Outcomes of Impacts and Explosions to NEO Surface and Interior Properties
- JPL Navigation Office
  - Primitive Body Proximity Navigation

Office of Chief Technologist (OCT)

Space Technology Grand Challenges

An open call for cutting-edge technological solutions that solve important space-related problems, radically improve existing capabilities or deliver new space capabilities altogether. These challenges are designed to initiate thought and discussion among our nation's innovators about future NASA missions and related national needs.

- Expand Human Presence in Space
- Manage In-Space Resources
  - Near-Earth Object Detection and Mitigation - Develop capabilities to detect and mitigate the risk of space objects that pose a catastrophic threat to Earth.
- Enable Transformational Space Exploration and Scientific Discovery
  - New Tools of Discovery - Develop novel technologies to investigate the origins, phenomena, structures and processes of all elements of the solar system and of the universe

Work with other Agencies and Nations

Other USG Agencies

- Continue to explore data sharing with DoD SSA Assets
- Planning Emergency Response exercise with FEMA and others

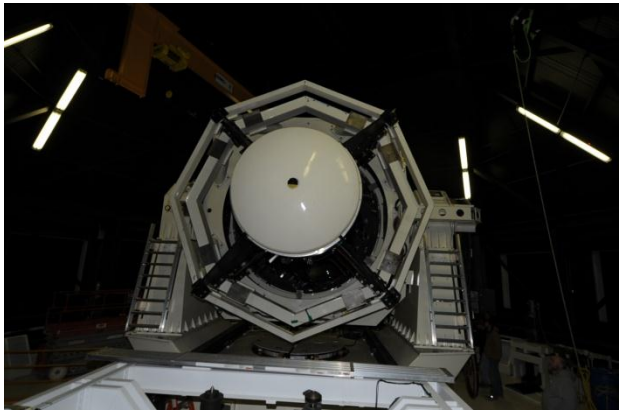
International Activities

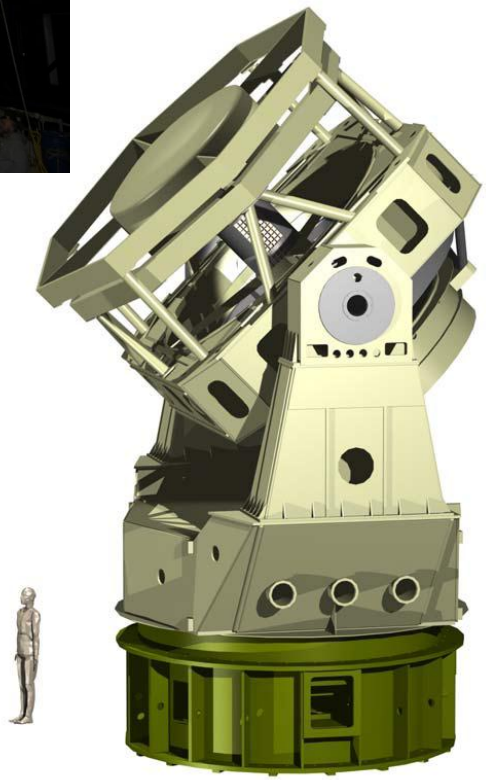
- Work thru construct of UN COPUOS S&TSC NEO Group
  - Finalize Terms of Reference and institute Mission Planning & Ops Group
  - First meeting of Int'l Asteroid Warning Network committee in Fall 2012
  - First meeting of MPOG in late Fall 2012 or Winter 2013
- Hosting of 3rd Int'l Planetary Defense Conference
  - April 15-19, 2013, in Flagstaff, AZ
- Support to int'l mission concept studies

Future Plans for NASA NEOO Program

Space SurveillanceTelescope

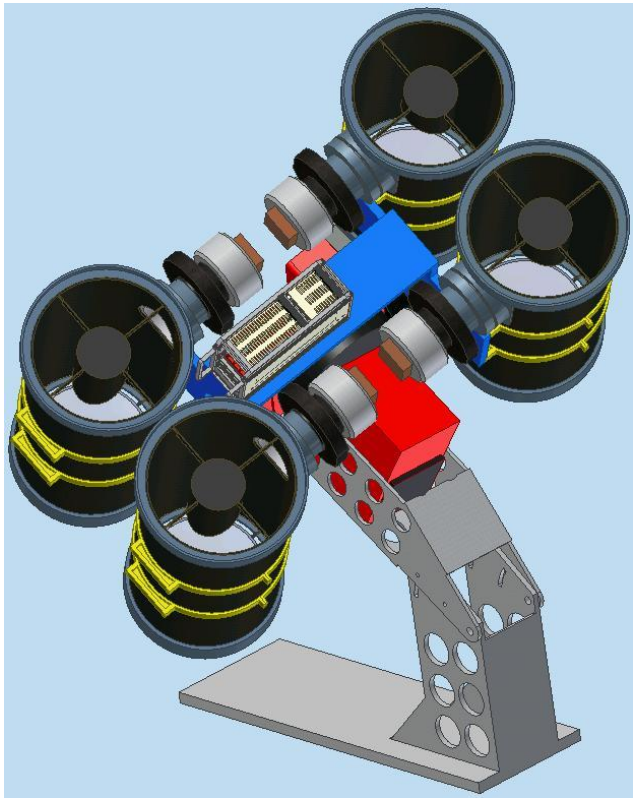
- **DARPA funded project**
- **Designed and built by MIT/LL**
  - **Same division as LINEAR**
- **Located Atom Peak, WSMR, NM**
- **3.6 meter primary mirror**
- **First Light was Feb 2011**
- **Started 1 year of checkout**
- **Eventual operations by AFSPC**
- **First of 3 to 4 worldwide sites**
- **Serendipitous detection of NEOs in background mode to space surveillance**





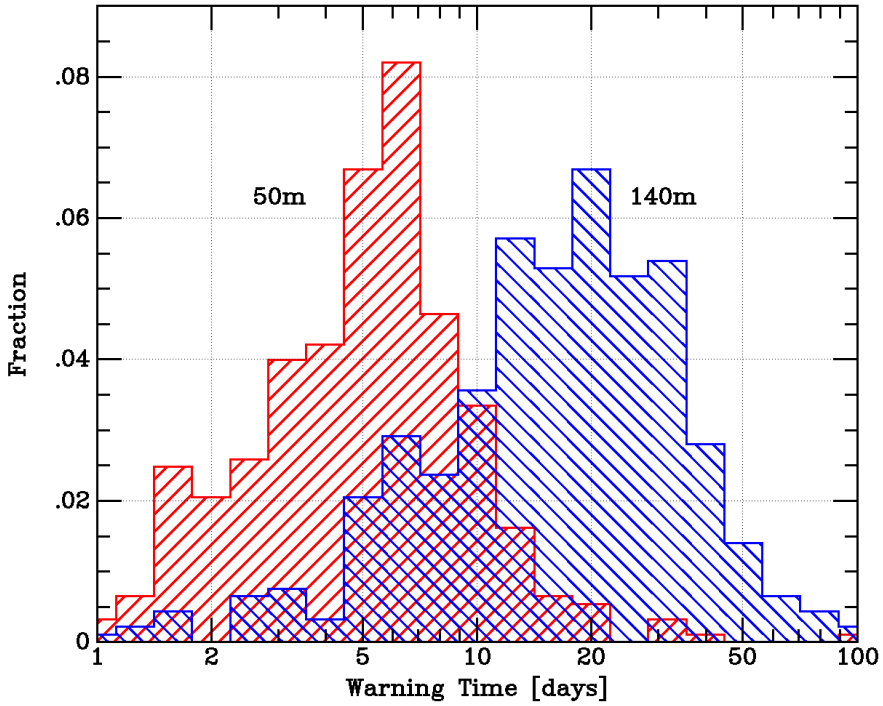
Near Term Impact Warning

Asteroid Terrestrial-impact Last Alert System –ATLAS*:
A project to patrol the entire night sky every night in search of incoming asteroids



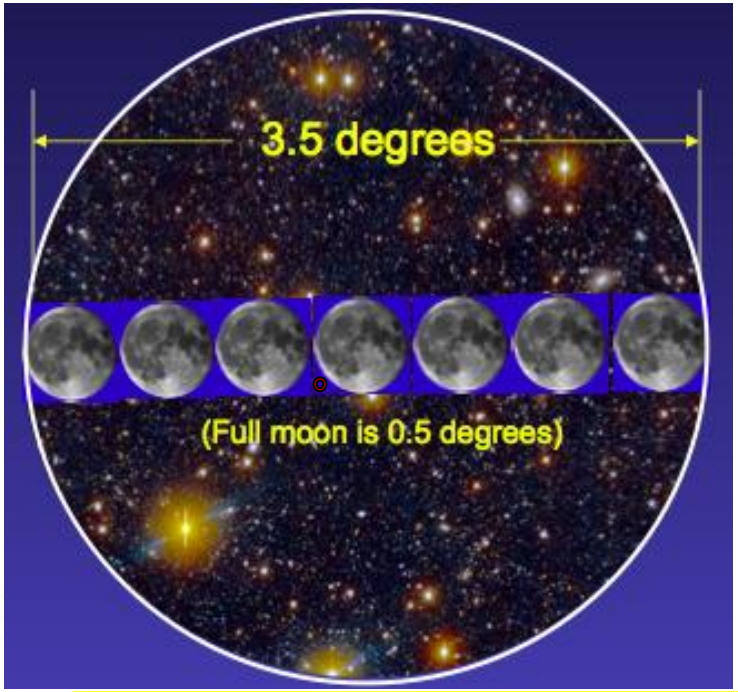
Proposed ATLAS telescope design

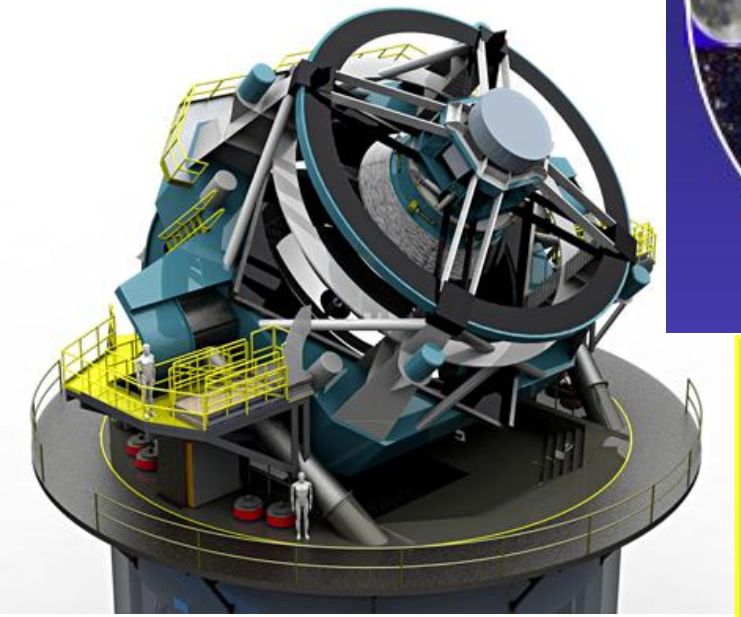
A geographically dispersed network (> 6 sites) of small coupled telescopes observing "shallow but wide" to provide more complete sky coverage for warning of near-term impact threats



*Courtesy University of Hawaii Institute for Astronomy

Large Synoptic Survey Telescope





- 6.4-m effective diameter
- 10 sq deg field of view
- ugrizy optical filters
- 18,000 square degrees ++
- 2x15s exposures + 2 more within 60 minutes
- Survey entire visible sky every 3-4 days in 2 filters for 10 years

Initial Operations 2019?