Near Earth Object Program

Presentation to

Small Bodies Analysis Group

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Program Executive

NASA HQ

12 Jan 2009

Terminology

- "Near Earth Objects (NEOs)"- any small body (comet or asteroid) passing within 1.3 astronomical unit (au) of the Sun
  - 1 au is the distance from Earth to Sun = ~ 150 million kilometers (km)
  - NEOs are predicted to pass within ~ 48 million km of Earth's orbit
  - e.g. any small body passing between orbits of Venus to Mars
  - Population of:
    - Near Earth Asteroids (NEAs)
    - Near Earth Comets (NECs) – also called Earth Approaching Comets (EACs)
      - 82 currently known
- "Potentially Hazardous Objects (PHOs)" – small body that has potential risk of impacting the Earth at some point in the future
  - NEOs passing within 0.05 au of Earth's orbit
    - ~ 8 million km = 20 times the distance to the Moon
  - Appears to be almost 20% of all NEOs discovered

NEO Observation Program

US component to international Spaceguard Survey

Has provided 98% of new detections of NEOs

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

Scientific Objective: Discover 90% of NEOs larger than 1 kilometer in size within 10 years (1998 – 2008)

NASA Authorization Act of 2005 provided additional direction (but no additional funding)

"…plan, develop, and implement a Near-Earth Object Survey program to detect, track, catalogue, and characterize the physical characteristics of near-Earth objects equal to or greater than 140 meters in diameter in order to assess the threat of such near-Earth objects to the Earth. It shall be the goal of the Survey program to achieve 90 percent completion of its near-Earth object catalogue (based on statistically predicted populations of near-Earth objects) within 15 years after the date of enactment of this Act."

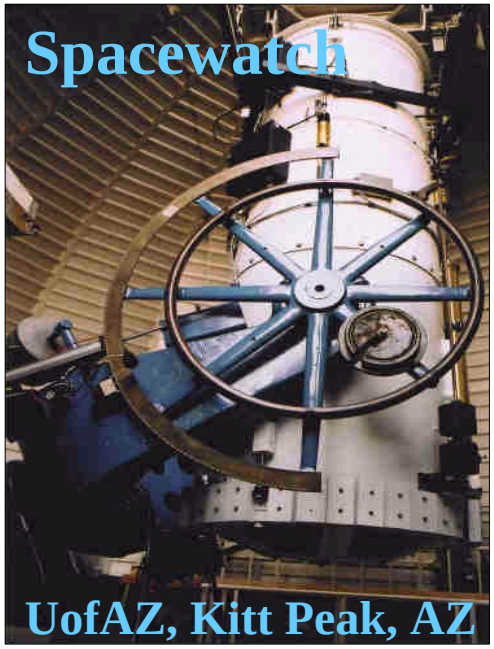
NASA's NEO Search Projects

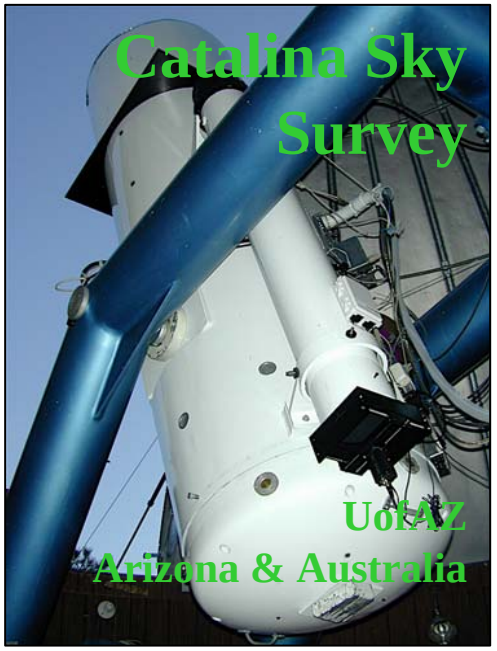
(at peak – 2005)

NEO Program Office @ JPL
- Program coordination
- Automated SENTRY

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

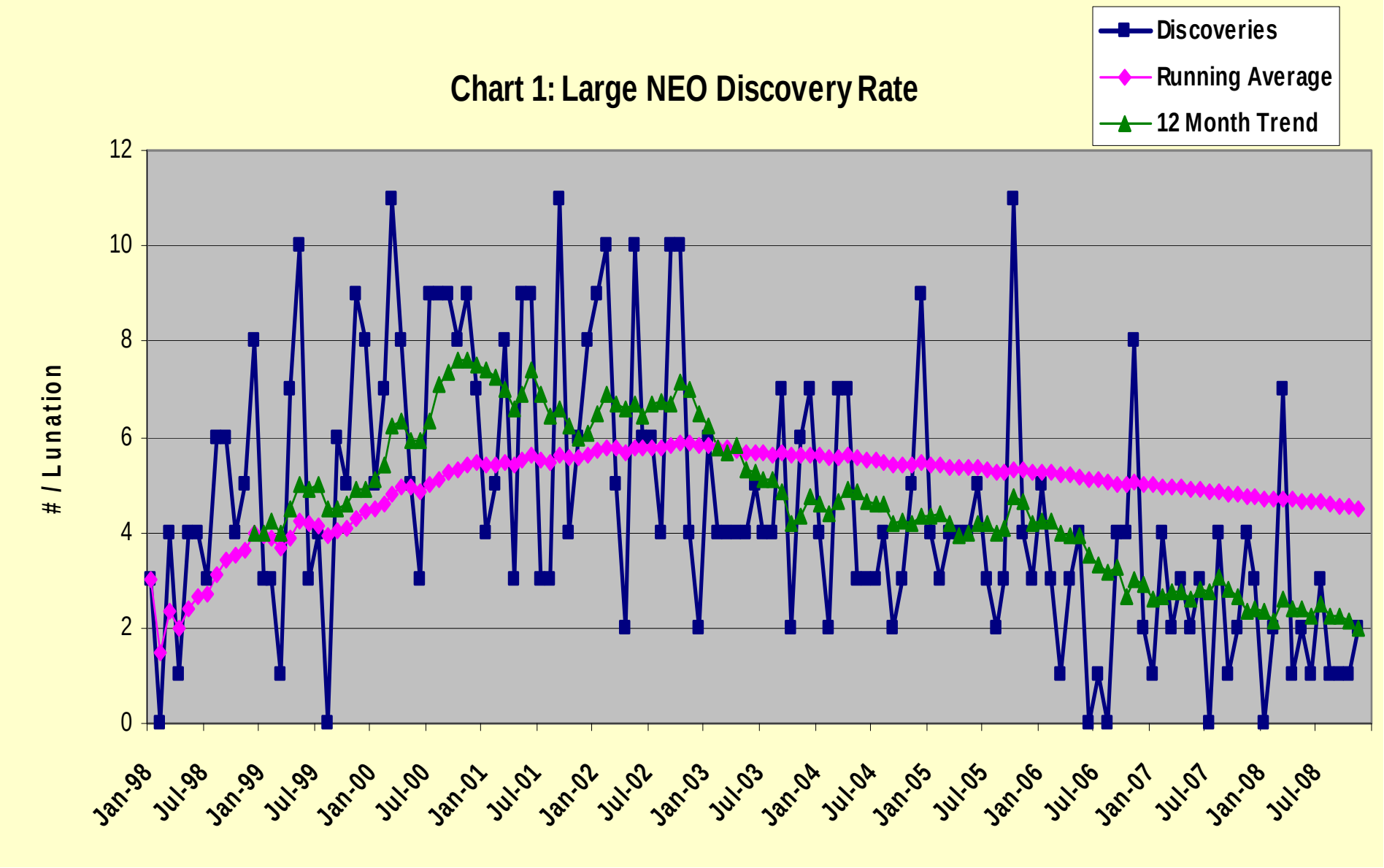
Minor Planet Center (MPC)
- IAU sanctioned
- Discovery Clearinghouse
- Initial Orbit Determination





Discovery Metrics

Discovery Rate of >1km NEOs



NASA's NEO Search Projects
(in 2009)

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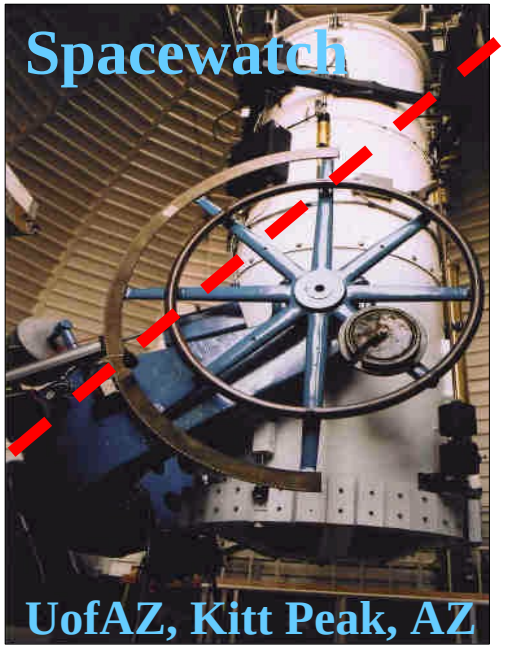
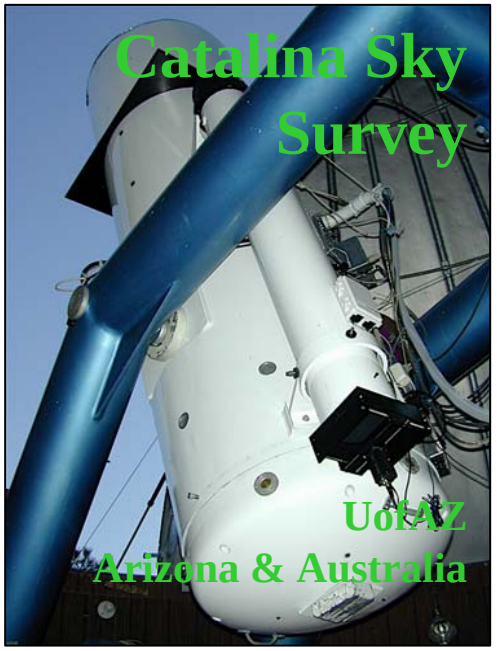
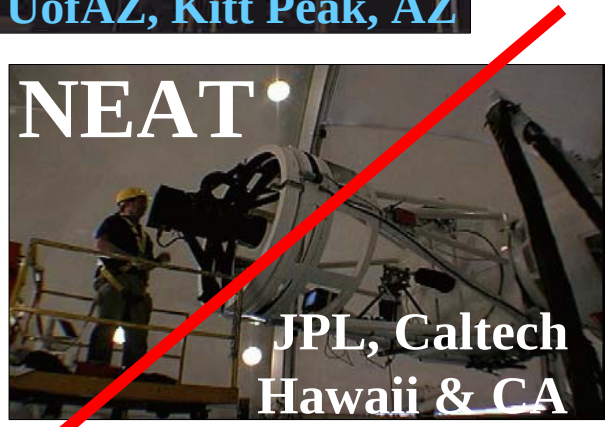
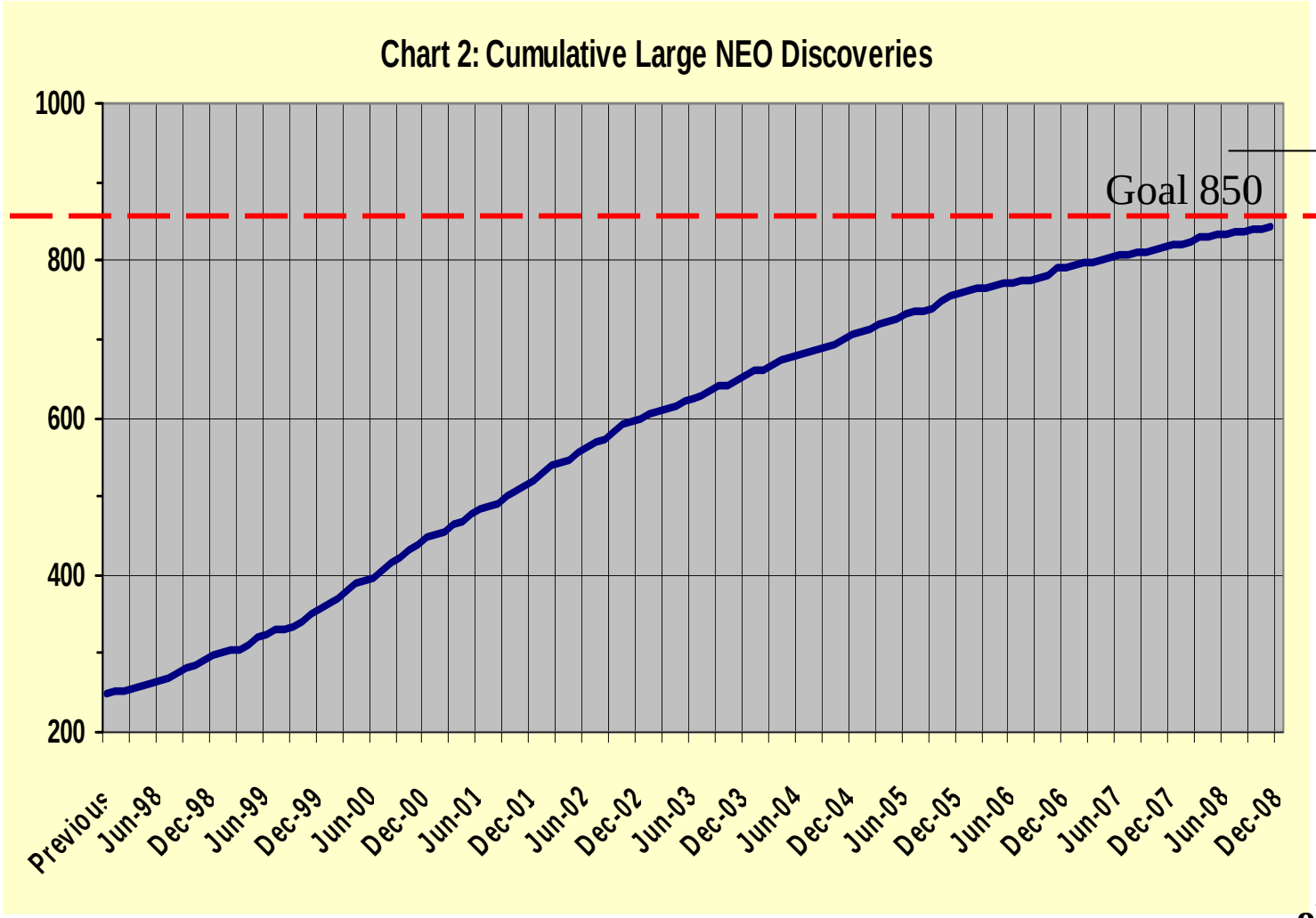
http://www.cfa.harvard.edu/iau/mpc







Discovery Metric



Estimated Population 940±50

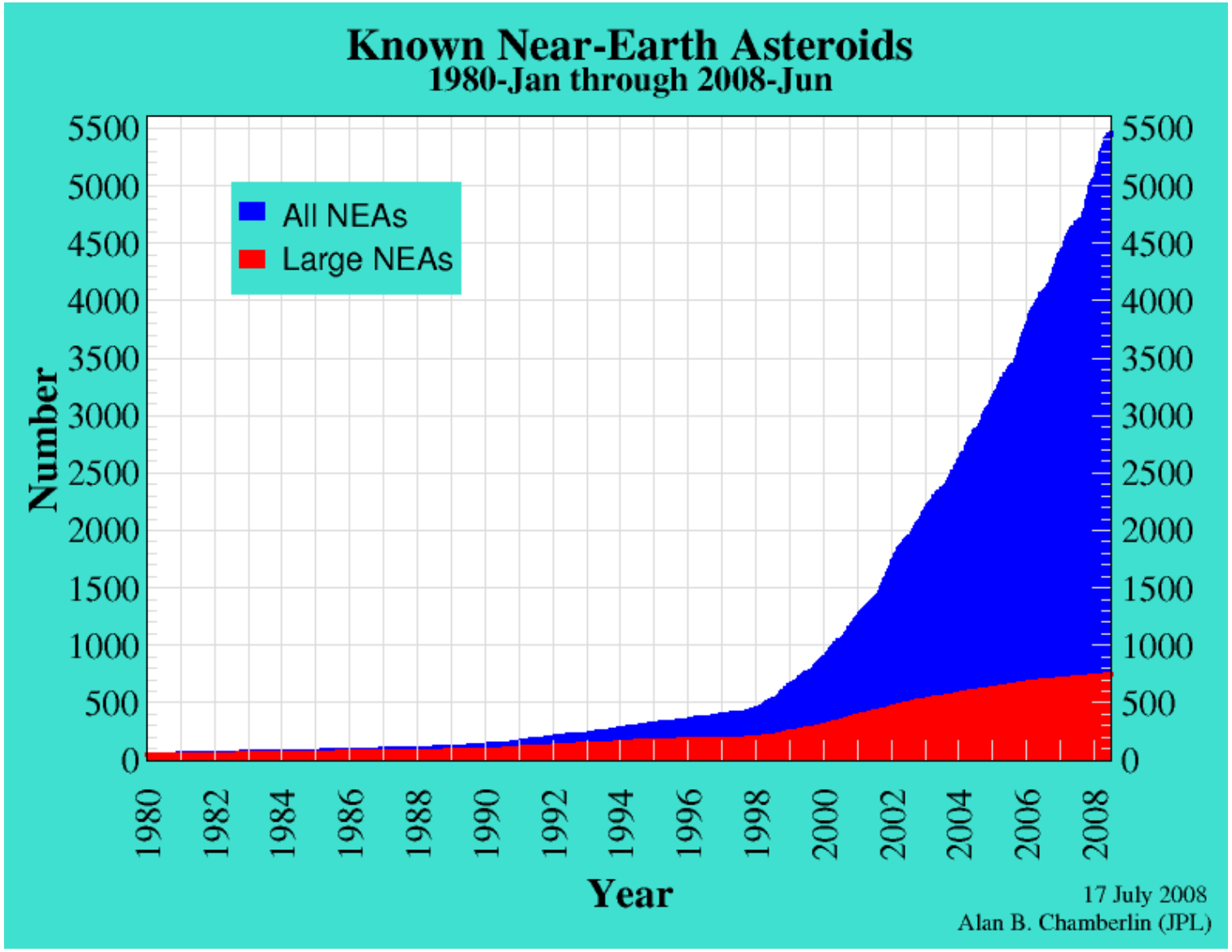
At current discovery rate, (2/month) we fall a little short of goal

844*
as of
01/01/09

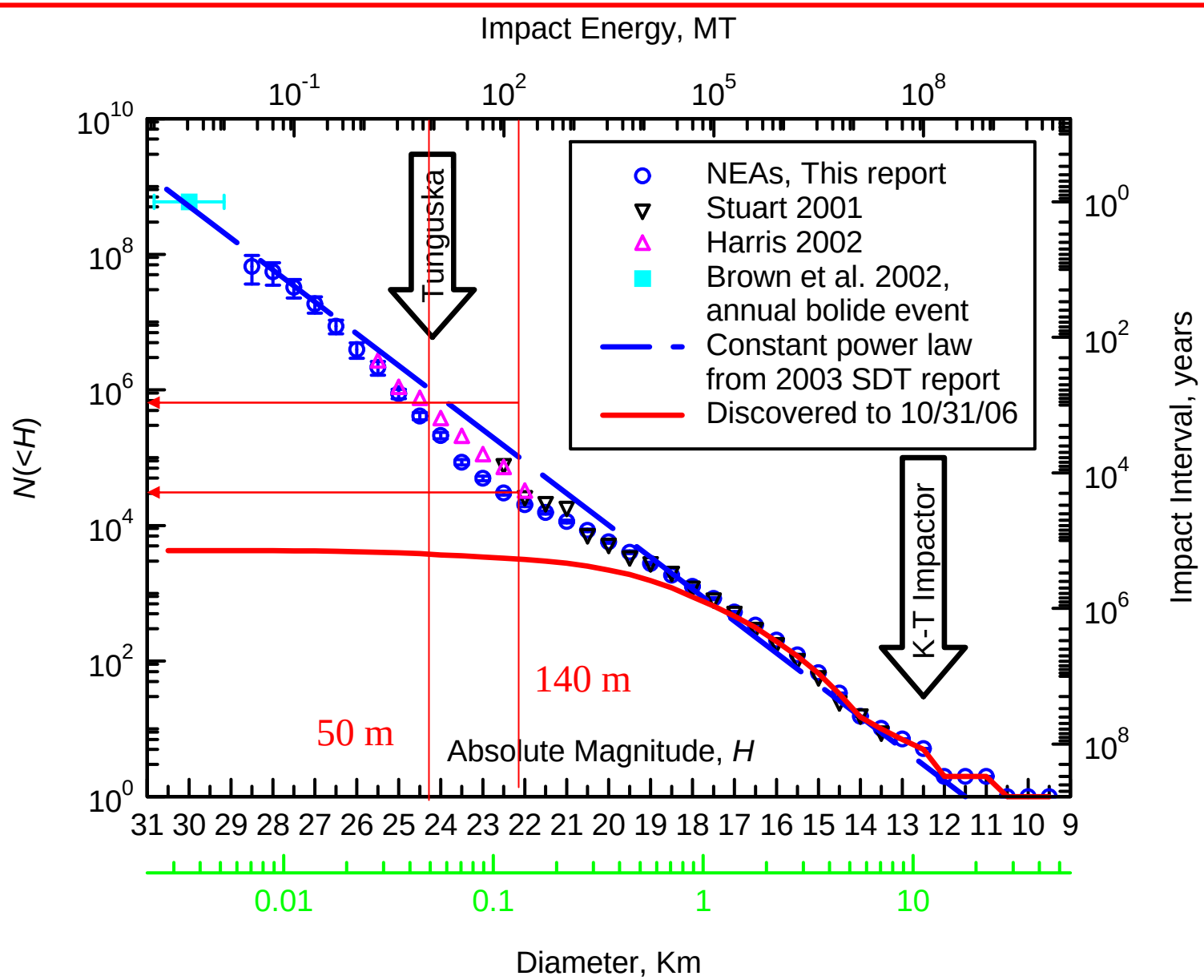
*Includes
82 NECs

5032 smaller objects also found, 1007 PHOs

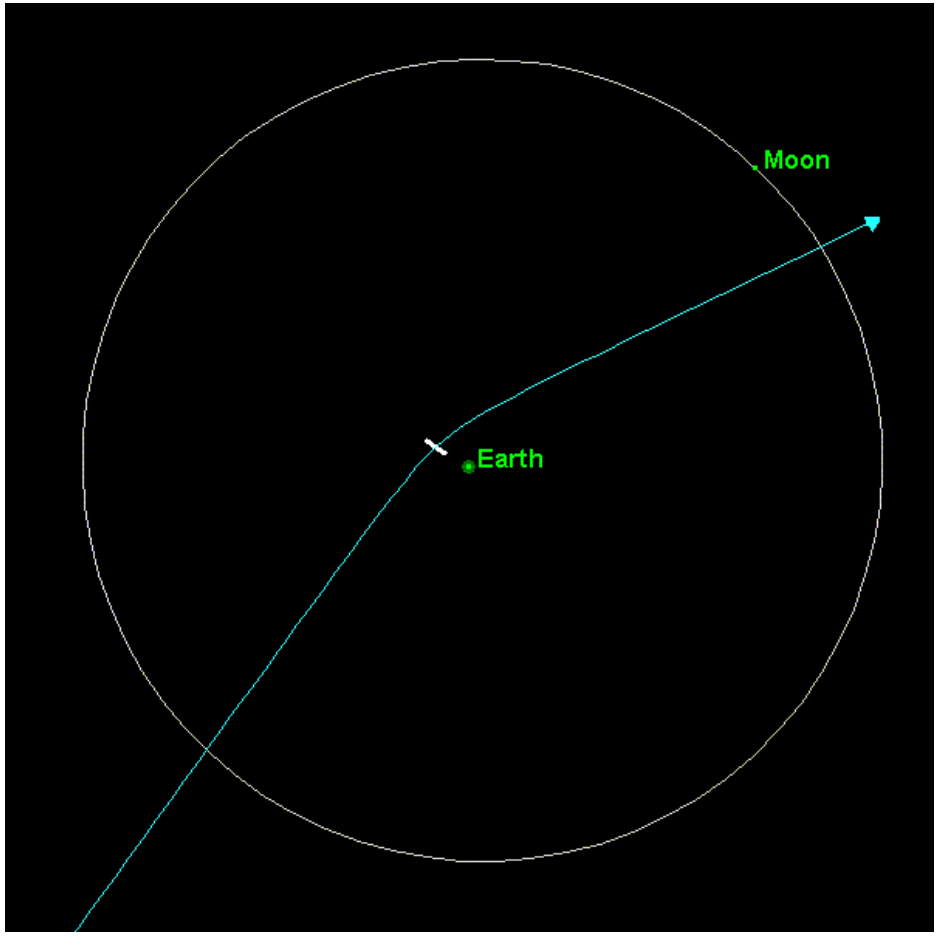
Known Near Earth Asteriod Population



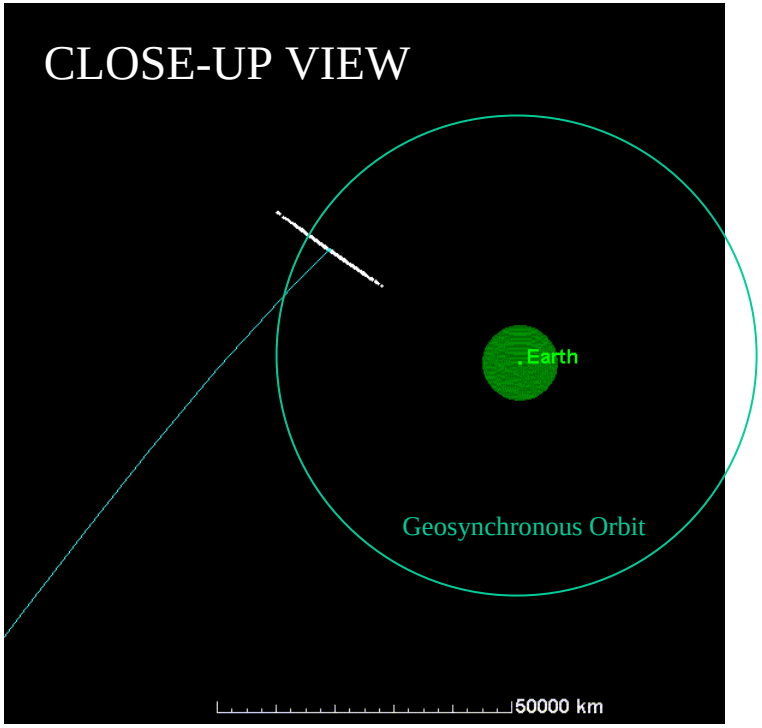
Frequency of NEOs by Size, Impact Energy, Brightness (Harris 2006)



Close Approachers



Predicted Close Approach of 2004 MN4 “Apophis” (an ~270m Object) on April 13, 2029



So far, five other PHOs of >100m size have threshold potential for impact in next 50 years

Return of Apophis!

These results were computed on May 06, 2008

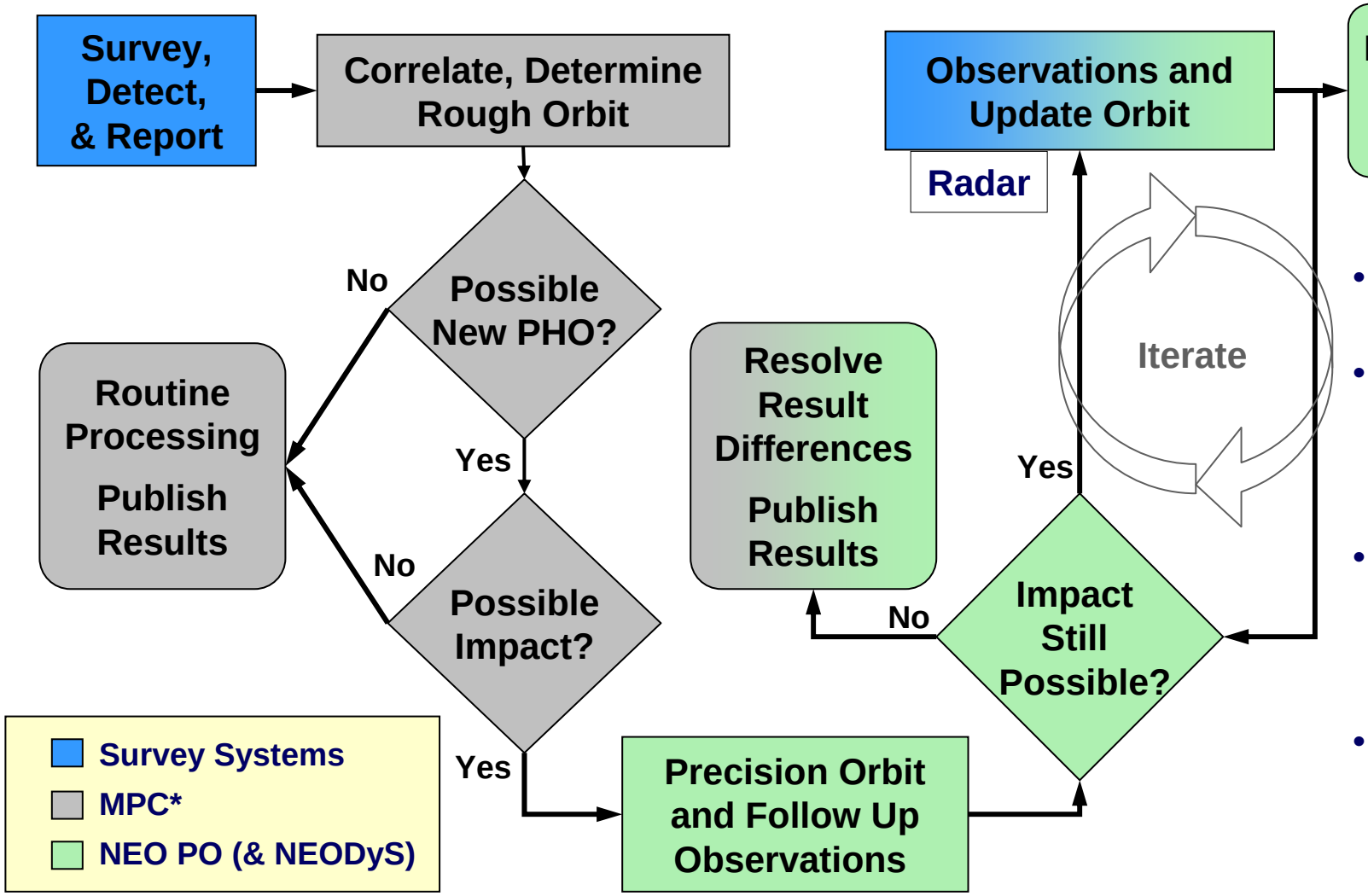
99942 Apophis (2004 MN4)

Earth Impact Table

Date	Distance	Width	Sigma Impact	Sigma LOV	Stretch LOV	Impact Probability	Impact Energy	Palermo Scale	Torino Scale
YYYY-MM-DD.DD	(r_{Earth})	(r_{Earth})			(r_{Earth})		(MT)		
2036-04-13.37	0.53	1.19e-03	0.000	-2.43132	1.60e+03	2.2e-05	5.06e+02	-2.42	0
2037-04-13.64	0.63	1.11e-03	0.000	4.12074	1.58e+03	8.1e-08	5.06e+02	-4.87	0
2069-04-13.08	0.46	0.00e+00	0.000	2.02831	1.85e+05	4.9e-07	5.06e+02	-4.41	0

Spaceguard Survey Catalog Program

Current Spaceguard Survey Infrastructure and Process

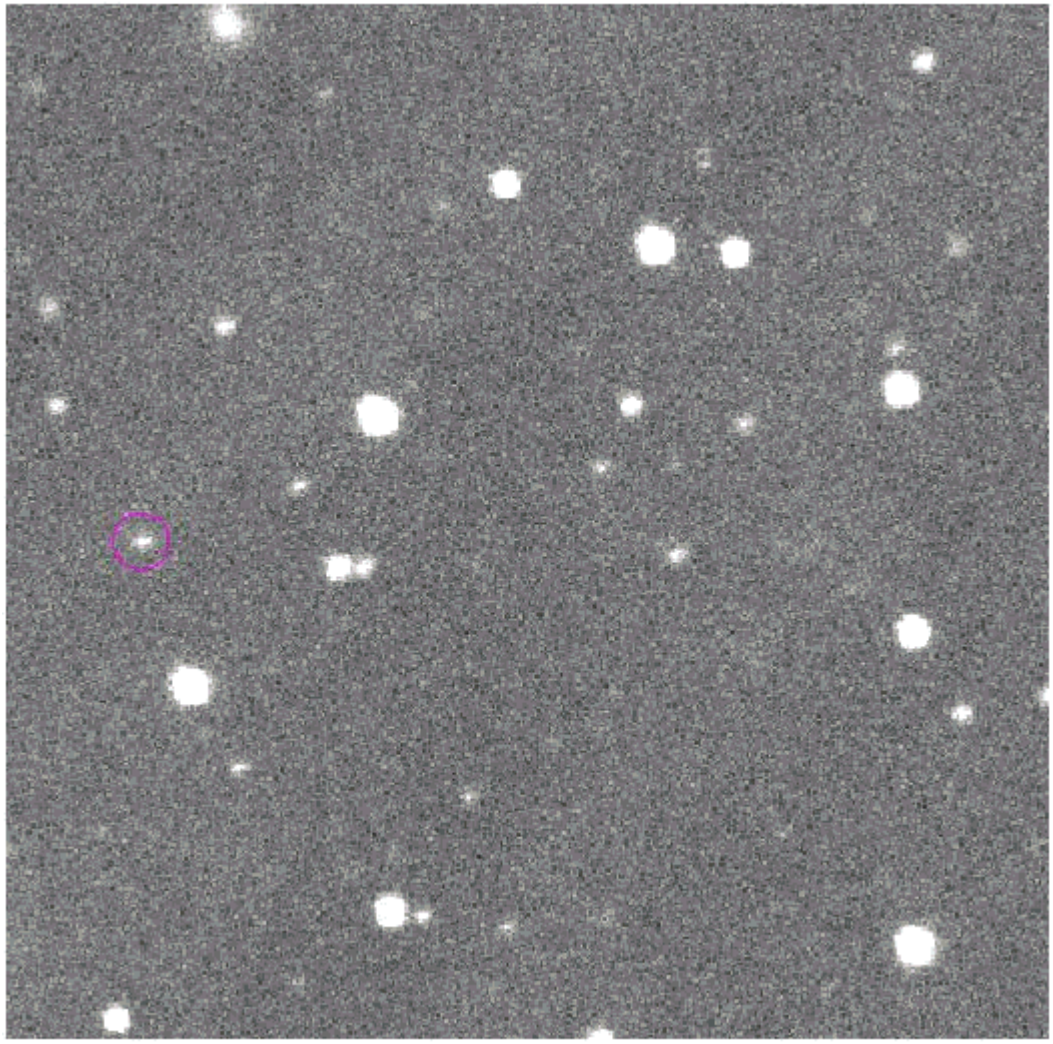


Alerts

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

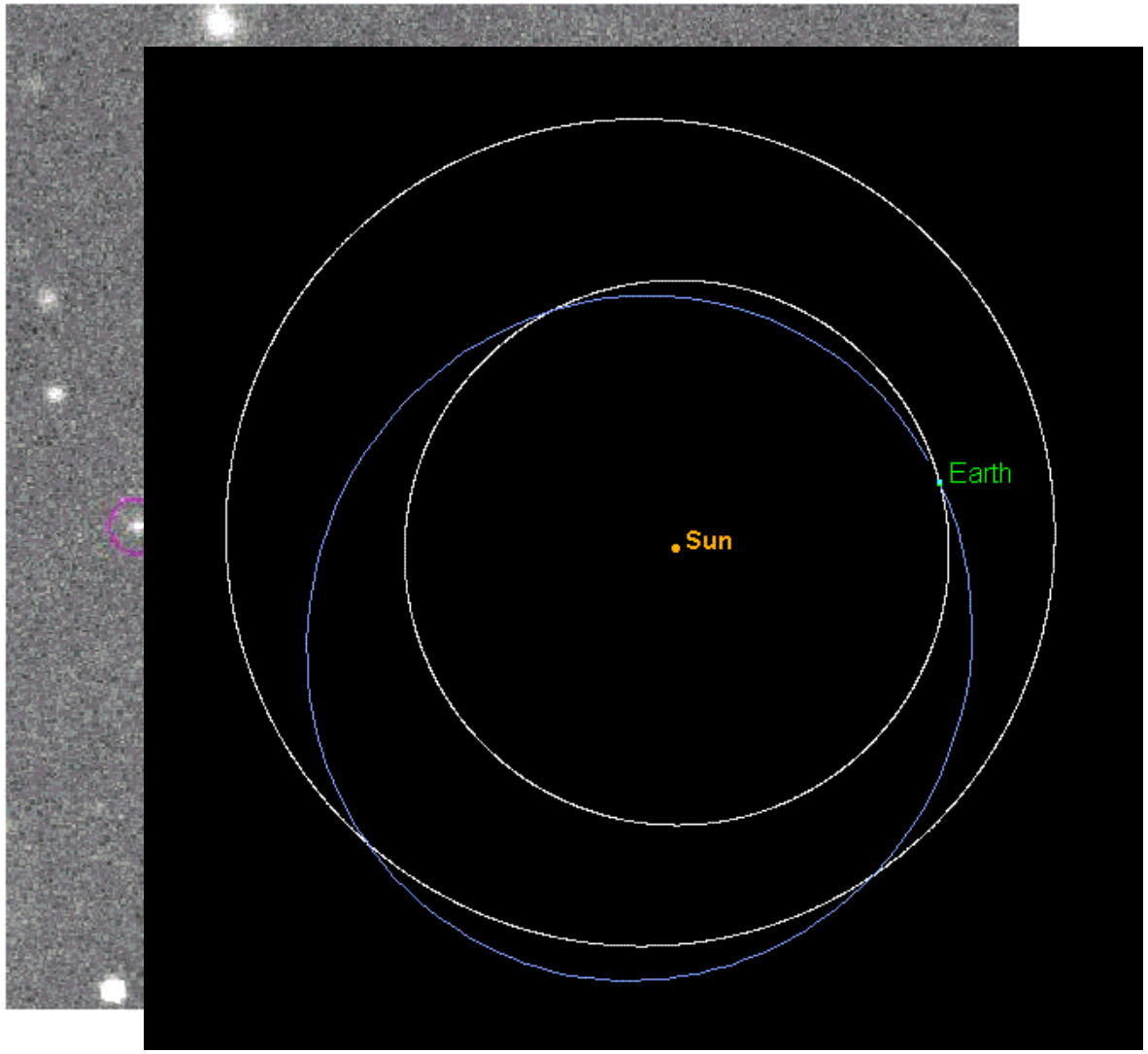
** Minor Planet Center*

The Short Life of 2008 TC3



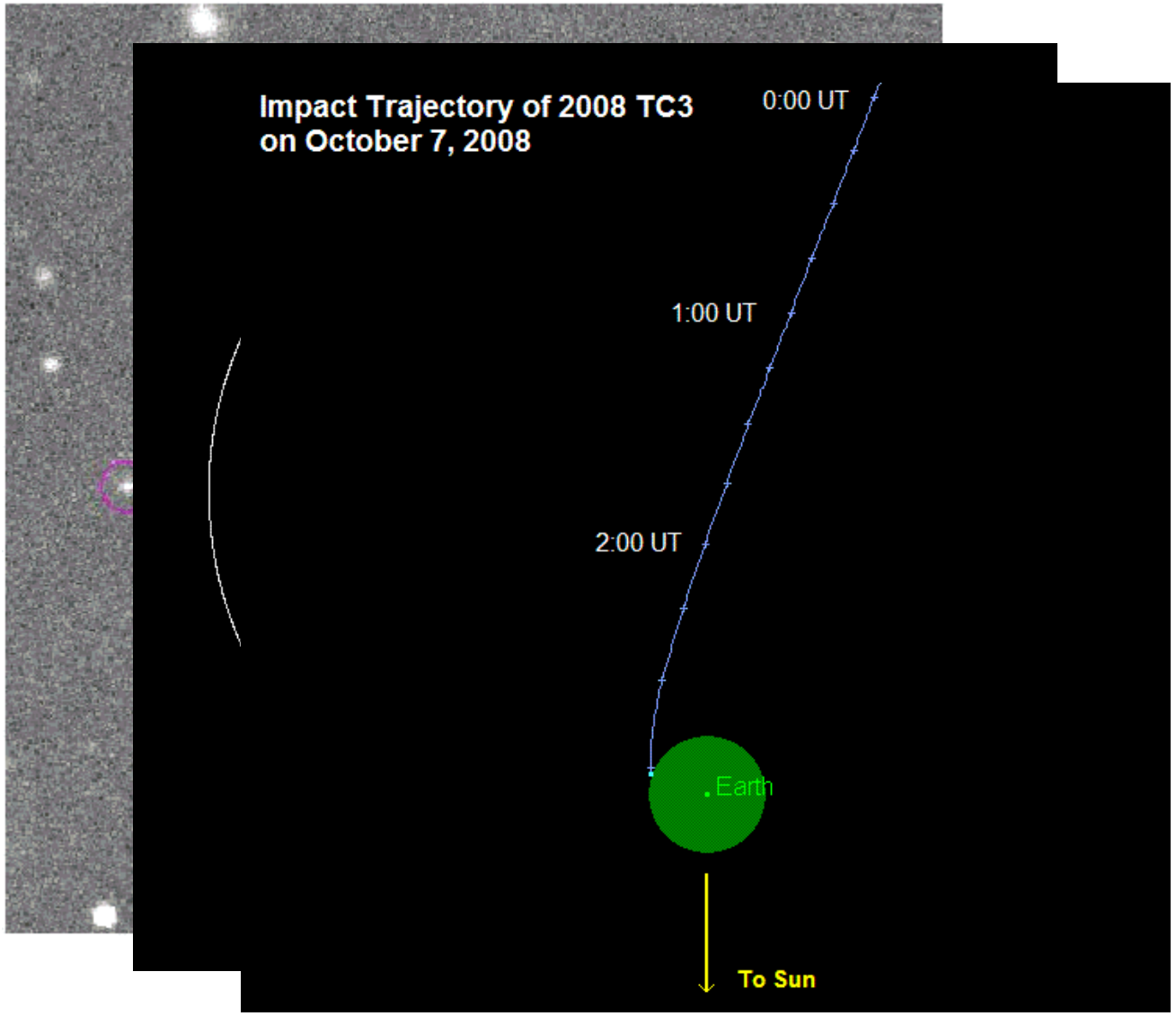
Discovered by
Catalina Sky Survey
Mt Lemmon Survey
Telescope (1.5m) at
0640 on Oct 6, 2008.
~19 Mv

The Short Life of 2008 TC3



Initial MPC orbit determination finds object will impact Earth within 24 hrs. MPC alerts JPL NEO Program Office and HQ NASA

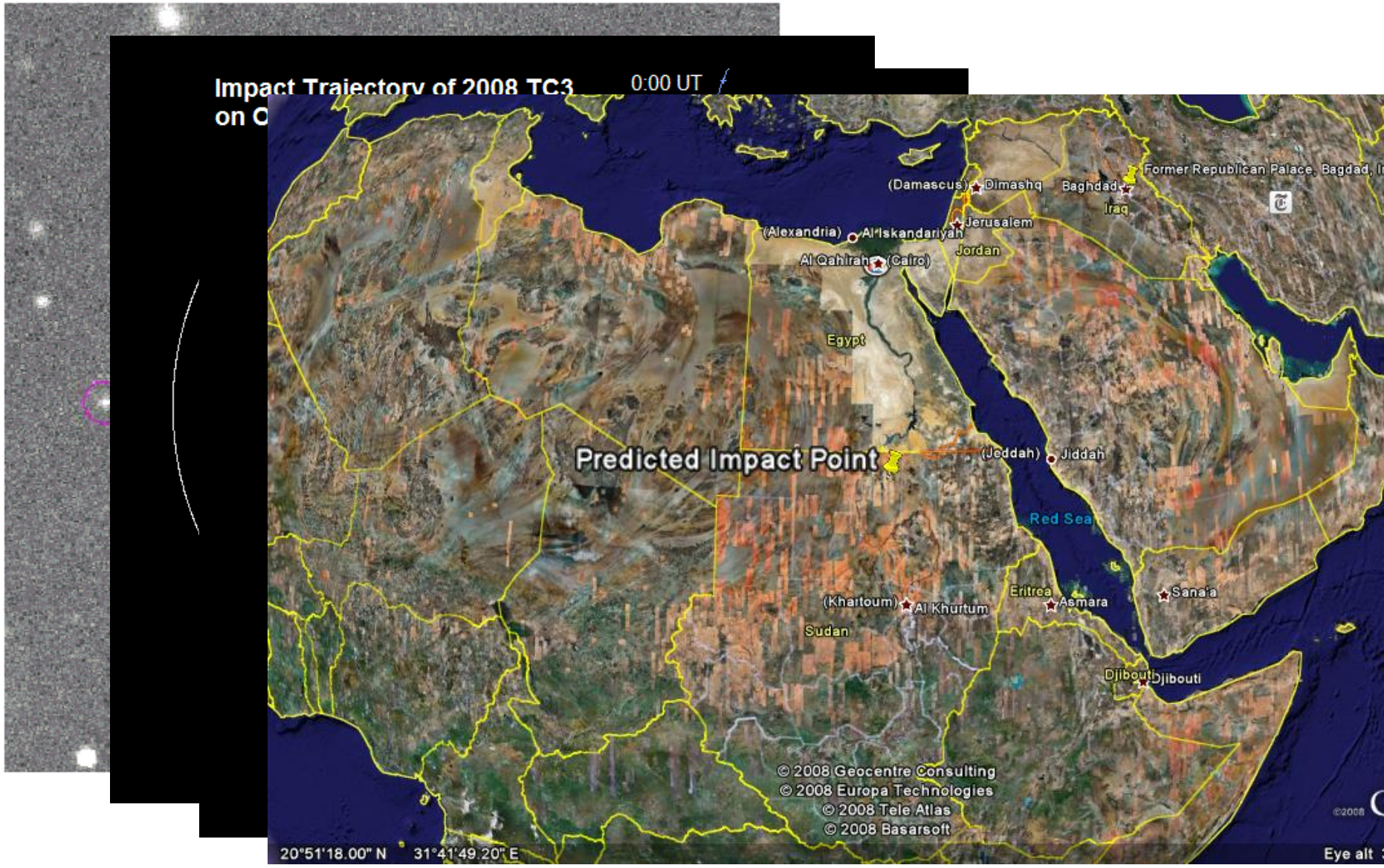
The Short Life of 2008 TC3



JPL SENTRY run predicts impact at 0245 on 7 Oct, 2008 over northern Sudan

Community responds with 570 observations from 27 observers

The Short Life of 2008 TC3



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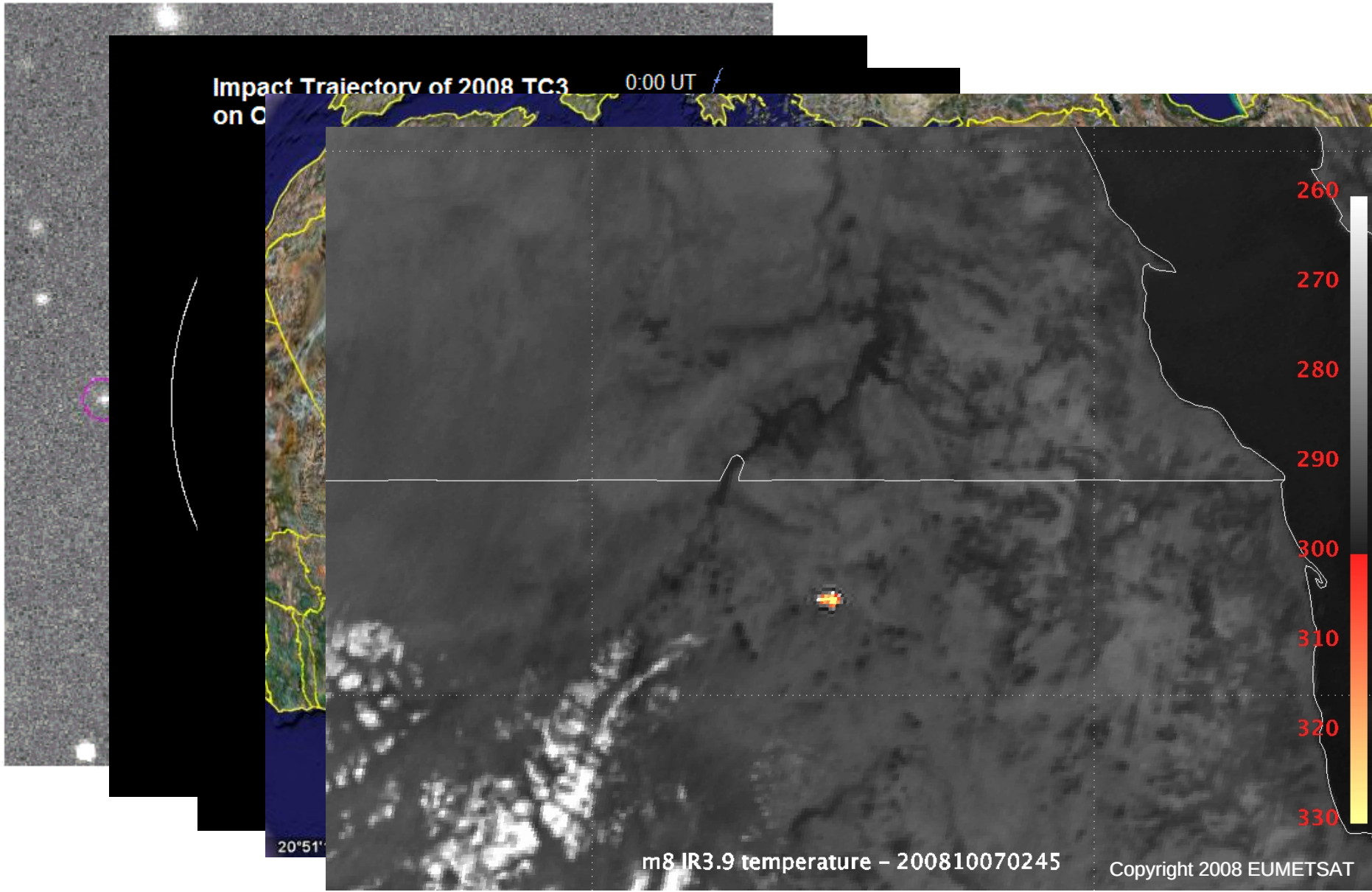

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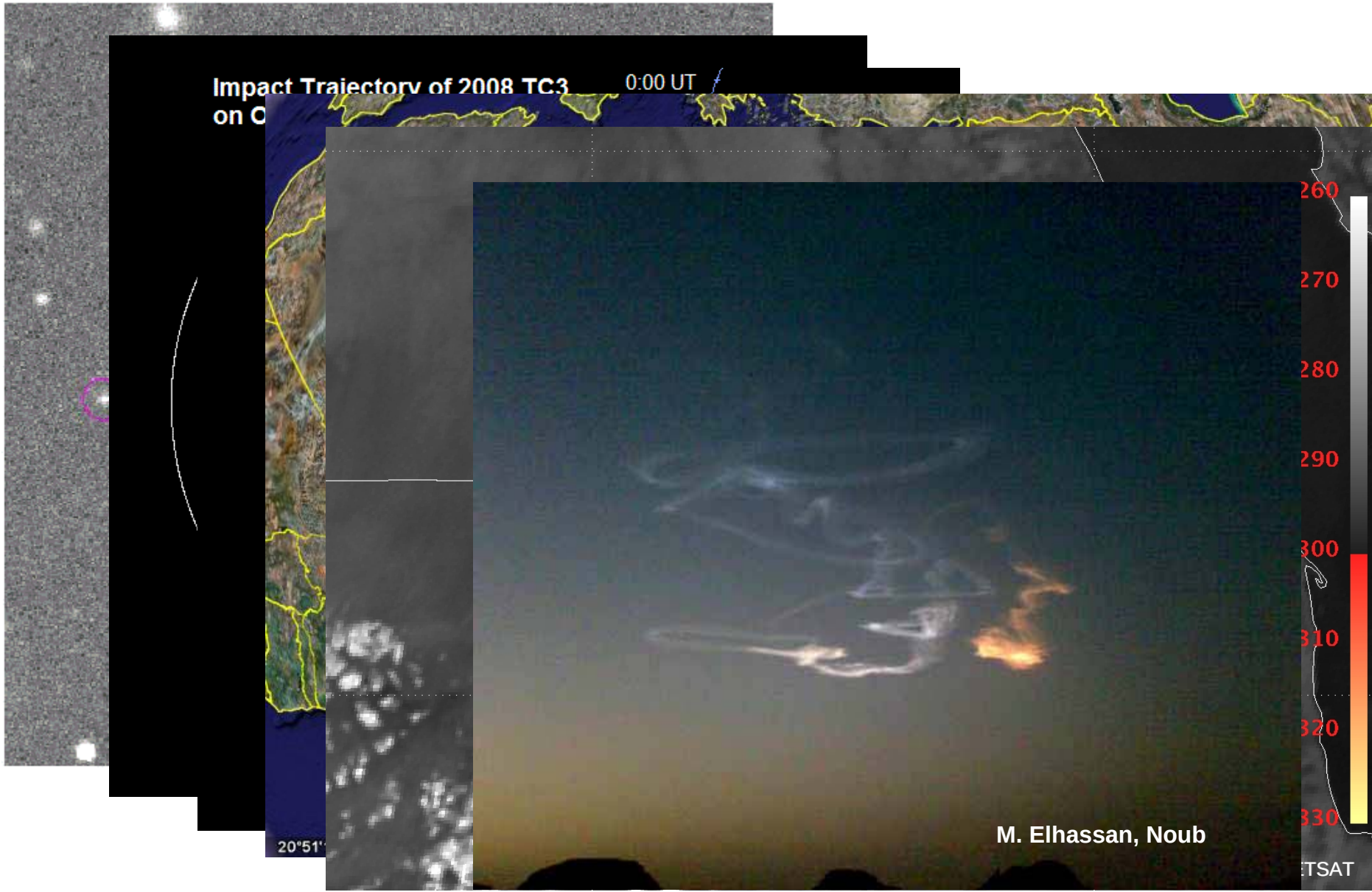
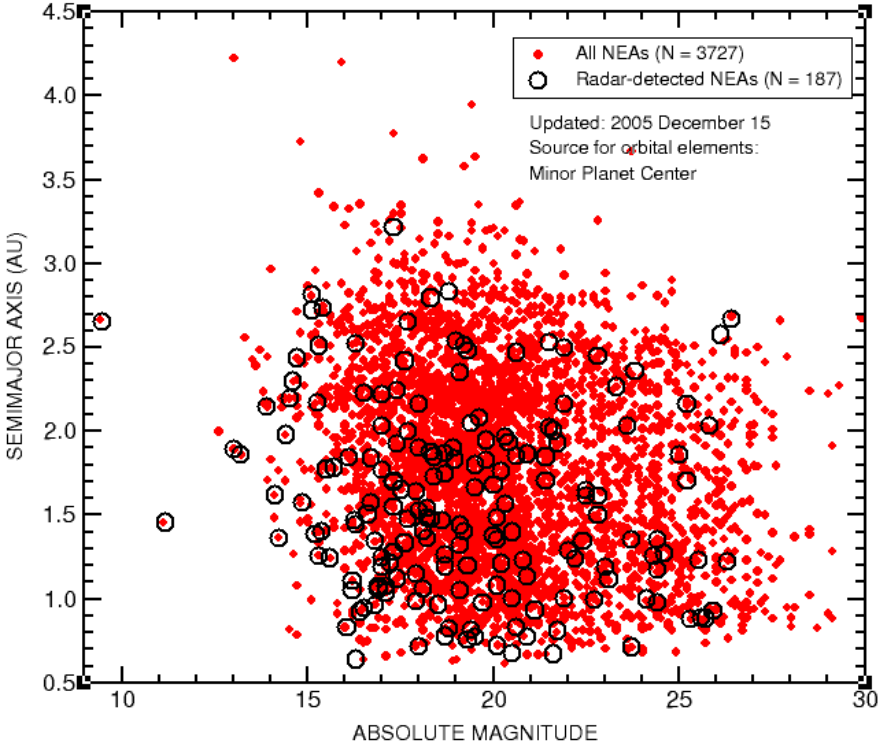
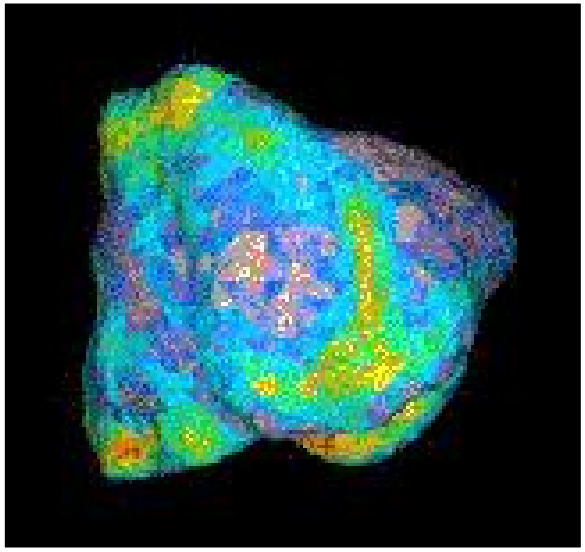


Radar Studies

- Observations on the limited accessible objects
  - 25 to 35 NEOs/year from Goldstone and Arecibo
  - Required for timely precision orbit determination
  - Shape modeling with sufficient signal strength





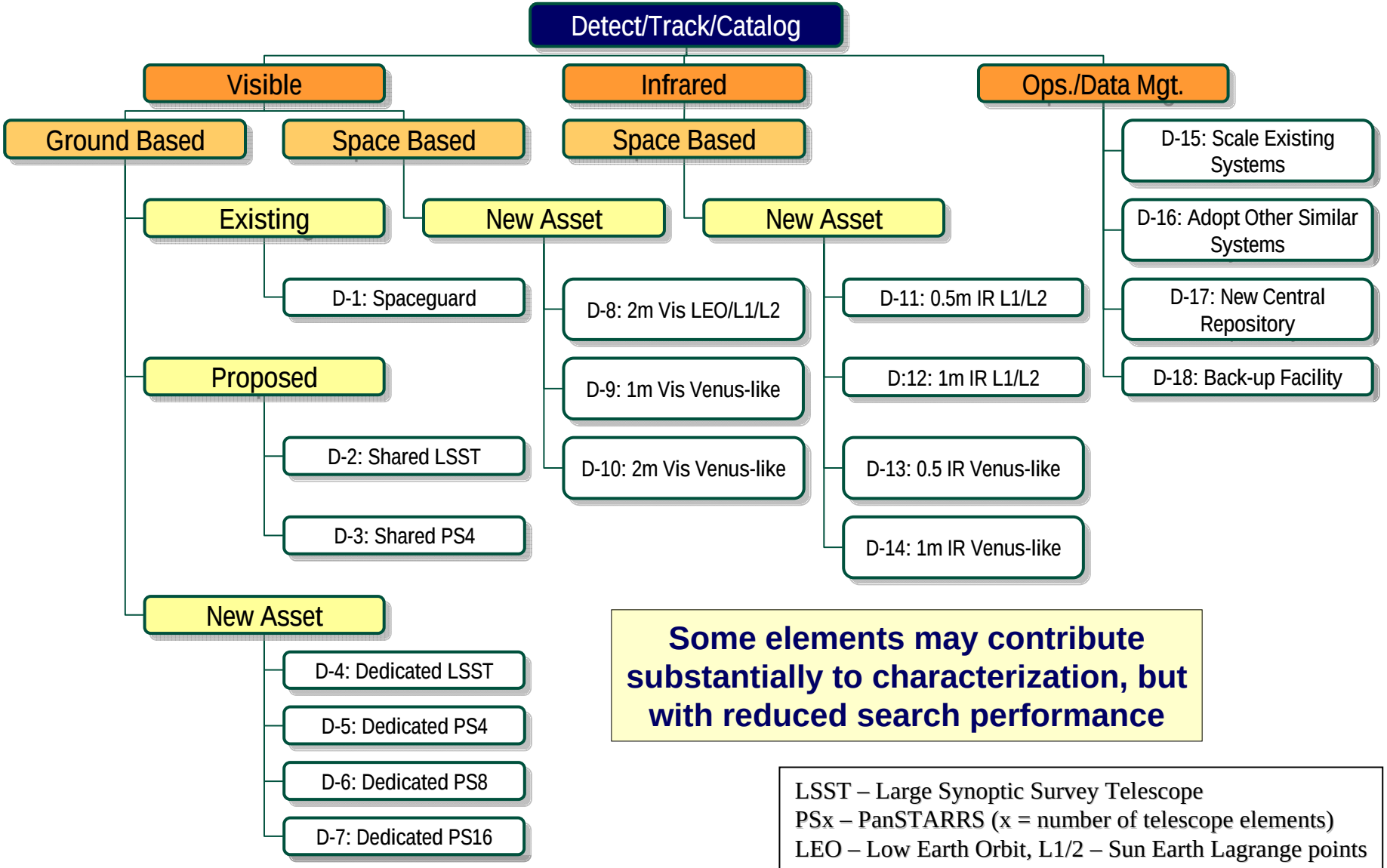
NASA AUTHORIZATION ACT OF 2005
Direction for Extended Search

"The Congress declares that the general welfare and security of the United States require that the unique competence of the National Aeronautics and Space Administration be directed to detecting, tracking, cataloguing, and characterizing near-Earth asteroids and comets in order to provide warning and mitigation of the potential hazard of such near-Earth objects to the Earth"

"The Administrator shall plan, develop, and implement a Near-Earth Object Survey program to detect, track, catalogue, and characterize the physical characteristics of near-Earth objects equal to or greater than 140 meters in diameter in order to assess the threat of such near-Earth objects to the Earth. It shall be the goal of the Survey program to achieve 90 percent completion of its near-Earth object catalogue (based on statistically predicted populations of near-Earth objects) within 15 years after the date of enactment of this Act."

"The Administrator shall transmit to Congress not later than 1 year after the date of enactment of this Act an initial report that provides the following:
(A) An analysis of possible alternatives that NASA may employ to carry out the Survey program, including ground- based and space-based alternatives with technical descriptions.
(B) A recommended option and proposed budget to carry out the Survey program pursuant to the recommended option.
(C) Analysis of possible alternatives that NASA could employ to divert an object on a likely collision course with Earth."

Detection and Tracking Options Trade Tree



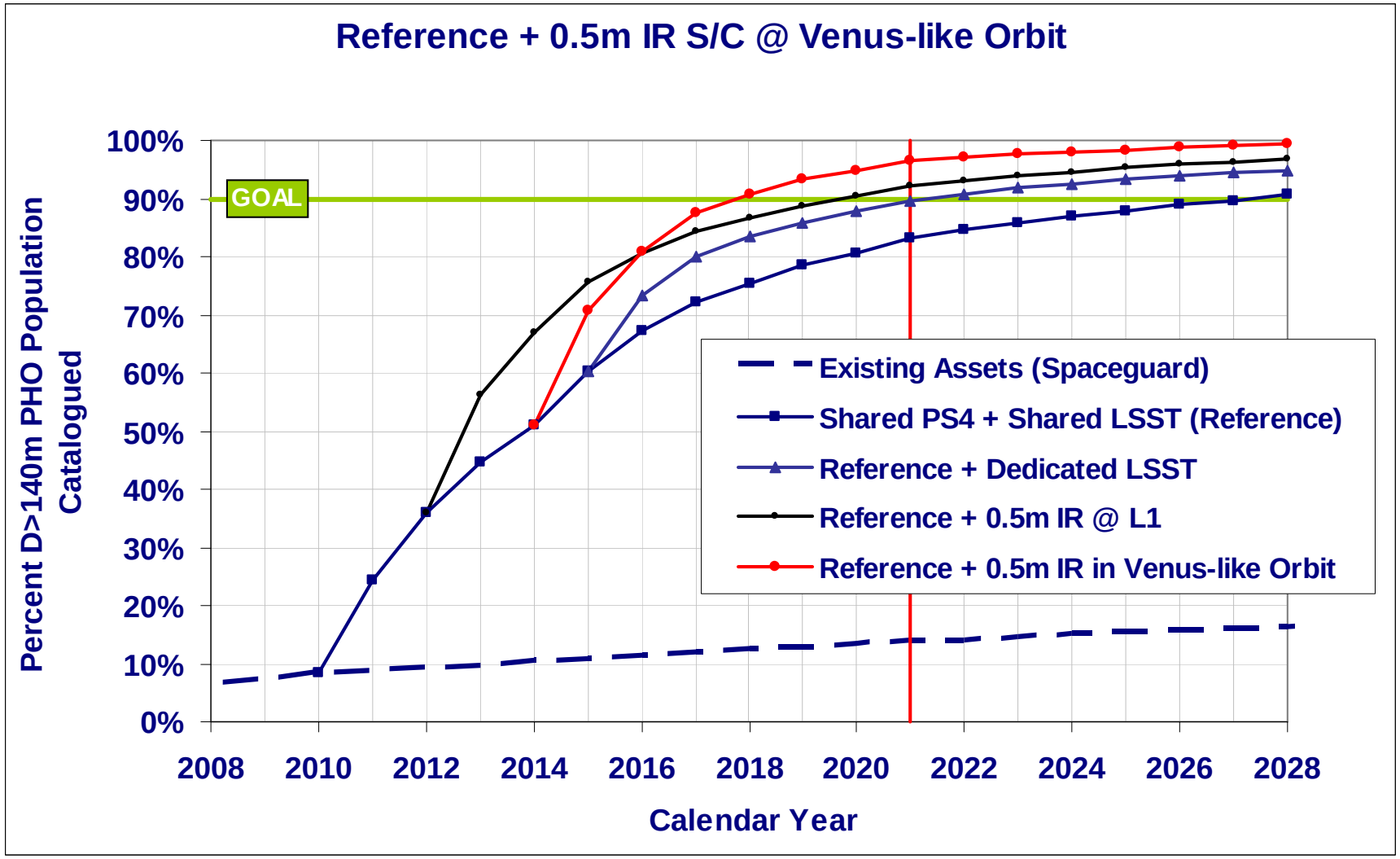
Some elements may contribute substantially to characterization, but with reduced search performance

LSST – Large Synoptic Survey Telescope
PSx – PanSTARRS (x = number of telescope elements)
LEO – Low Earth Orbit, L1/2 – Sun Earth Lagrange points
Vis – visible band, IR – InfraRed band

NEO Analysis of Alternatives

Bottomline: Accomplishment of legislated goal requires dedicated asset(s)

- At modest additional cost (+~$800M LCC), space based option best technical solution



Survey Analysis of Alternatives Findings: Detection, Tracking, and Warning

- Combining shared PS4 (USAF) and LSST (NSF) with a dedicated NASA-funded ground-based asset can reach the 90% goal by the end of 2020
  - Other combinations of ground-based assets will achieve the goal later
  - Reliance on shared systems (PS4 and LSST) carries additional cost and schedule risks typical of inter-Agency collaborations

- Space-based infrared systems combined with the shared ground-based assets could reach the 90% goal up to 3 years early
  - Space-based IR systems have benefits beyond the congressional goals
  - Failure of a space mission could delay survey goal completion by up to 5 years and would fall-back on shared ground-based assets to reach 90% goal

- A portion of the survey could be achieved by PS4 and LSST without NASA involvement, depending on the search strategies they implement

- The expanded survey could generate up to 40 times more close approach warnings than current systems
  - PS4 could generate 2-3 warnings per week as early as 2010

NEO Analysis of Alternatives Study Results

- Studied existing, planned, proposed and conceptual systems to perform expanded survey
  - Ground-based and space-based

Findings:

- No single envisioned system completely accomplishes goal
- Combined architecture of planned ground-based survey telescopes coupled with an additional dedicated asset could achieve goal

NASA Recommendation: The program continue as currently planned, but the agency will also take advantage of opportunities to use potential dual-use telescopes and spacecraft—and partner with other agencies as feasible—to attempt to achieve the legislated goal within 15 years.

Report to Congress is at:
http://www.nasa.gov/pdf/171331main_NEO_report_march07.pdf

NEOO Program II

Potential New Elements

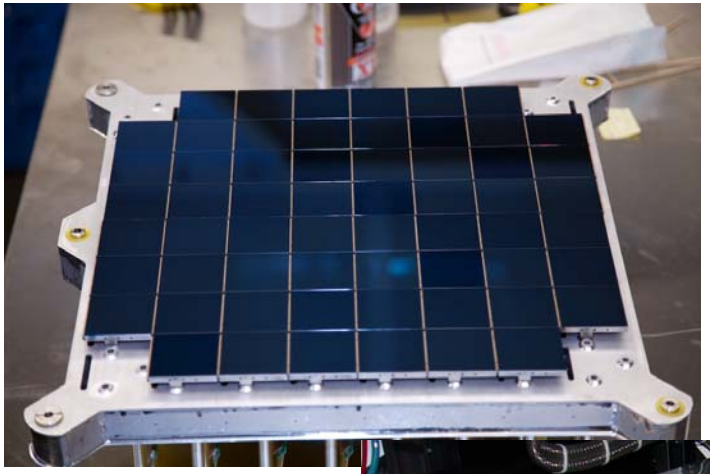
Ready to Implement

- MPC II - Second Generation Minor Planet Center
- NEOSSat – Near Earth Object Surveillance Satellite – Canadian Space Agency
- Pan-STARRS NEO – Partnership with Panoramic Survey Telescope and Rapid Response System for NEO Survey upgrades and operations
  - Most potential to complete 1 km survey, soon to be operational
- Planetary Radar – Maintenance of Radar capabilities at Arecibo and Goldstone
- WISE for NEOs – Upgrades for Wide-field Infrared Survey Explorer mission to process & archive data and extend mission for NEO detection

Requires Further Definition

- DCT, IRTF, etc Upgrades – For NEO capabilities at:
  - Discovery Channel Telescope – Lowell Observatory 4 meter
    - Wide FOV Camera for NEO and KBO detection, follow-up
  - Infra-Red Telescope Facility Instruments
    - Polarimeter, CSHELL2, NEO NIR Spectrograph
- LSST NEO – Partnership with NSF on NEO capabilities for Large Synoptic Survey Telescope (moving object detection S/W and operations
- “NEOStar” – Space-based NEO detection and tracking system.
  - 0.5 / 1-meter IR telescope in 0.7 AU orbit (Venus trailing) for 100 meter NEO and other small body detection

Panoramic Survey Telescope and Rapid Response System (PanSTARRS)

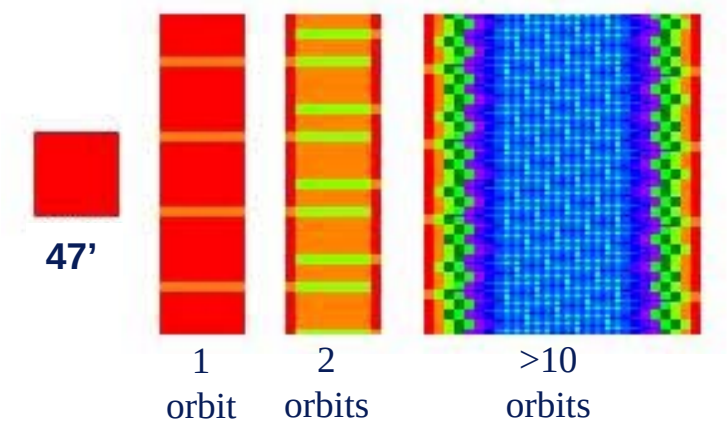


USAF Research Labs
R&D Project

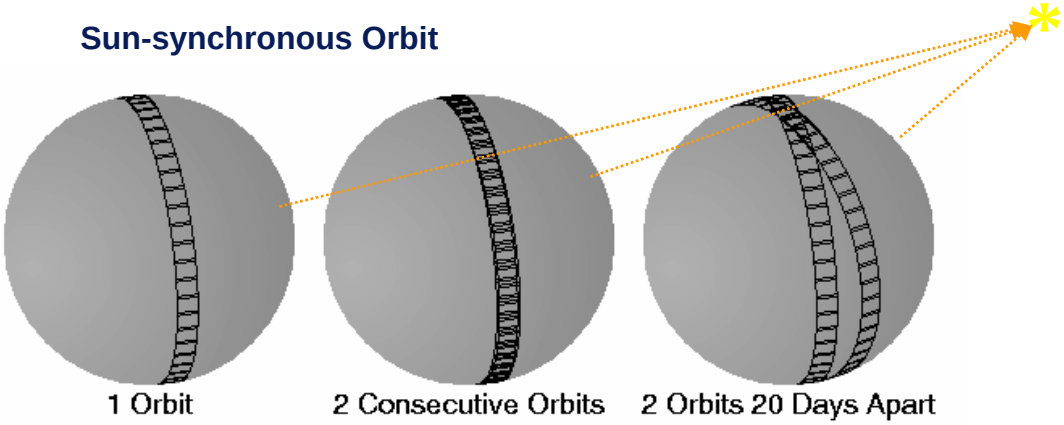
PS-1

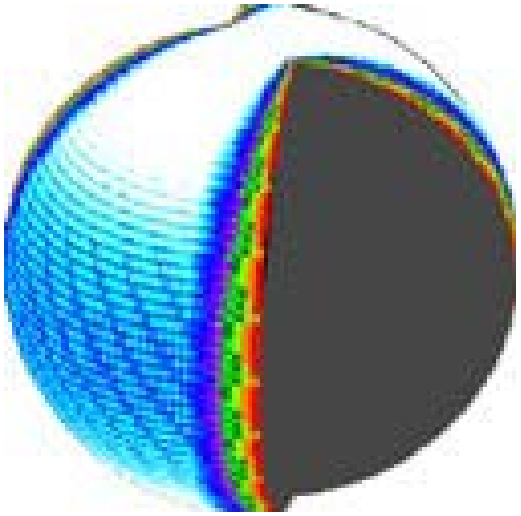
1.8 meter telescope
1.4 giga-pixel camera

How WISE will Operate



As WISE IR imager scans around the sky over multiple orbits, an extensively overlapped all sky image is built over 6 months

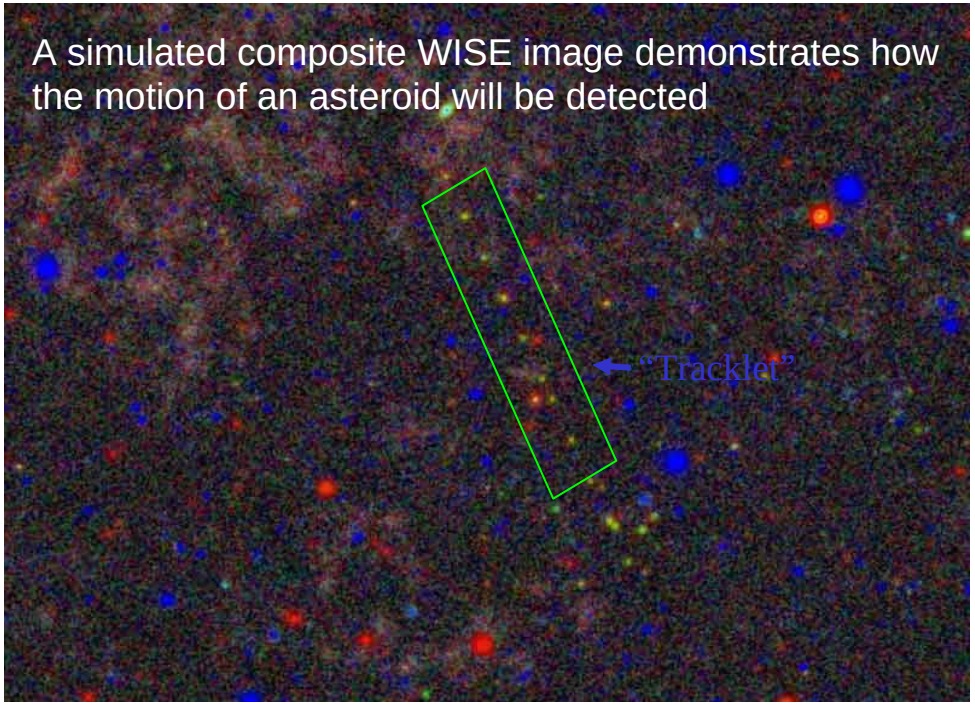


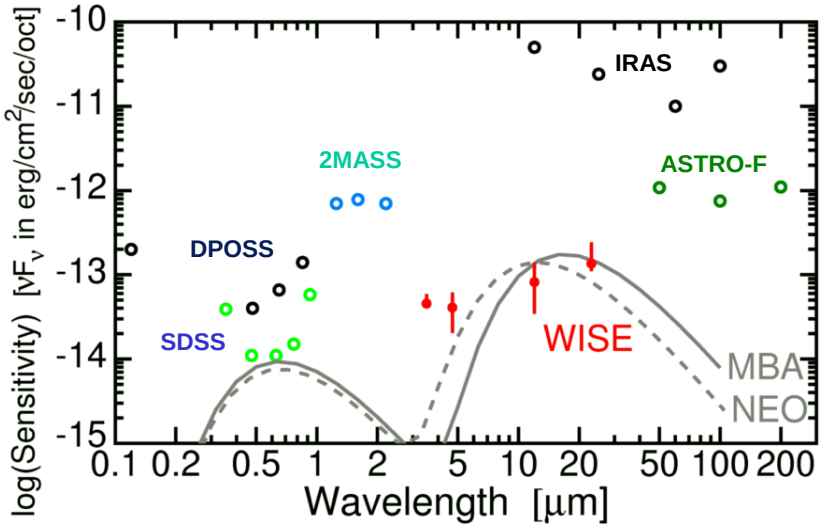


After ~ 3 months

How WISE will Detect Asteroids

- Asteroids are brighter in the IR than in the optical.
- They move in the hours between WISE frames.
- For asteroids with known orbits, WISE sensitivity will be slightly better than for fixed celestial objects:
  - –Asteroids generally move in the same direction that WISE scans and thus can get more repeated observations than for stars.
  - –Asteroids' movement across the sky greatly reduces the confusion noise from unresolved celestial sources.





- WISE can get ~ 12 observations spaced about 3 hours apart, covering a total arc of 40 hours for NEOs.

- Walker (2005) has shown that WISE orbits are good enough to recover 80% of WISE discovered NEOs within a ground-based search FOV of 3 square degrees for 21 days.

2008 Omnibus Appropriations Act

"In order to assist Congress in determining the optimal approach regarding the Arecibo Observatory, NASA shall contract with the National Research Council to study the issue and make recommendations. As part of its deliberations, the NRC shall review NASA's report *2006 Near-Earth Object Survey and Deflection Study* – and its associated *March 2007 Near-Earth Object Survey and Deflection Study* as well as any other relevant literature. An interim report, with recommendations focusing primarily on the optical approach to the survey program, shall be submitted within 15 months of enactment of this Act. The final report, including recommendations regarding the optimal approach to developing a deflection capability, shall be submitted with 21 months of enactment of this Act. The NRC study shall include an assessment of the costs of various alternatives, including options that may blend the use of different facilities (whether ground- or space-based), or involve international cooperation. Independent cost estimating should be utilized."

NASA Authorization Act of 2008

Title VIII – Near Earth Objects

•***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.*

International Activities - UNCOPUOS

- NEO Working Group established under Science and Technical Subcommittee of Committee on Peaceful Uses of Outer Space
  - Annual Meeting (February in Vienna) with “intersession” work
  - Facilitate international collaboration on NEO issues
  - Encourage more participation from member states
- Current WG effort centers around threat determination and information dissemination to member states

Closing Thought

The space program could leave humanity few greater legacies than to know the time and place of any cosmic destruction, allowing ample time to prepare adequate response to that inevitable event.

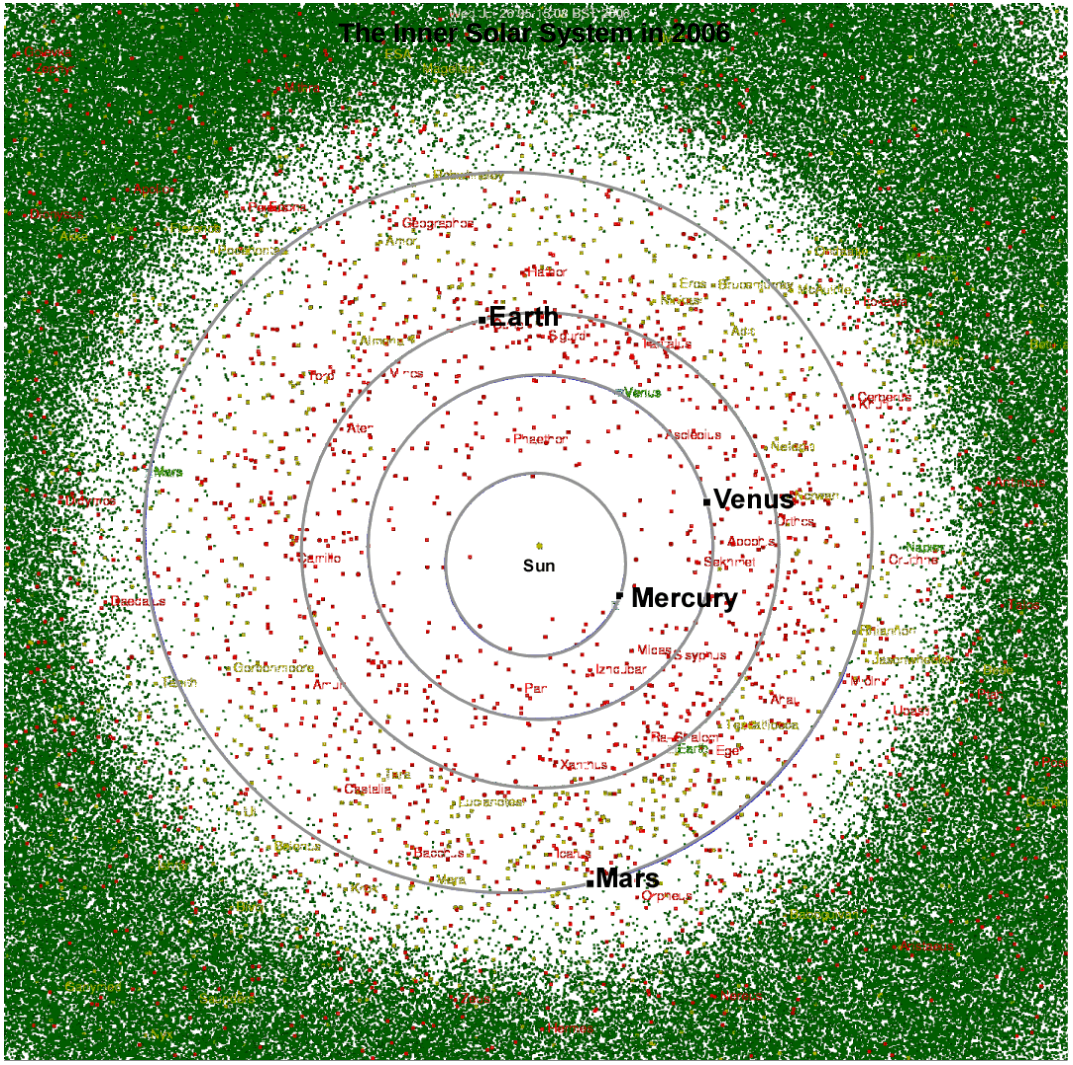
Back-ups

History of Known NEO Population

2006

Earth Crossing

Outside Earth's Orbit



Known

- **338,186 minor planets**
- **4159 NEOs**
- **789 PHOs**

New Survey Will Likely Find @ > 140m

- **66,000+ NEOs**
- **18,000+ PHOs**

Scott Manley

Impact Frequencies and Consequences

Type of Event	Diameter of Impact Object	Impact Energy(MT)	Average Impact Interval (years)
High altitude break-up	**< 50 m**	**<5**	**1 - 50**
Tunguska-like event	**> 50 m**	**>5**	**250 - 500**
Regional event	**> 140 m**	**~150**	**5,000**
Large sub-global event	**> 300 m**	**~2,000**	**25,000**
Low global effect	**> 600 m**	**~30,000**	**70,000**
Medium global effect	**> 1 km**	**>100K**	**1 million**
High global effect	**> 5 km**	**> 10M**	**6 million**
Extinction-class Event	**> 10 km**	**>100M**	**100 million**

Effects of TUNGUSKA EVENT

June 1908 – 100 years ago