



Report from NASA's Small Bodies Assessment Group to the Planetary Science Subcommittee

Nancy Chabot, SBAG Chair
March 31, 2015

Last SBAG Meeting:

- **January 6 – 7, 2015:** 12th SBAG Meeting, Phoenix, AZ
(Coordinated with *AstroRecon: Conference on Spacecraft Reconnaissance of Asteroid and Comet Interiors*, January 8-10, 2015 at ASU)



*Findings are summarized.
Full text of findings available on the SBAG website
(<http://www.lpi.usra.edu/sbag/findings/>)*

SBAG 12 Findings

A note on the SBAG findings process:

- 1) Discussion occurs at open community meetings; findings recommendations are solicited through open microphone discussion periods.
- 2) The SBAG Steering Committee meets, agrees on draft findings, writes and reviews findings over the next ~week.
- 3) The SBAG draft findings are posted to the SBAG website and the community is notified of a two week comment period; the community provides comments.
- 4) The SBAG Steering Committee reviews all comments, discusses and revises the findings as appropriate.
- 5) The final findings are posted to SBAG website.



Findings are summarized.

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SBAG 12 Findings

SBAG eagerly anticipates a banner year for small bodies science in 2015. While our science will advance across diverse fronts including telescopic, laboratory, and modeling investigations, the simultaneous spacecraft exploration of Ceres, the Pluto system, and comet Churyumov-Gerasimenko will focus public attention on small bodies science as never before. The anticipated flood of discoveries in 2015 is the fruit of decades of effort. ***The attention it will attract gives the small body science community a spectacular opportunity to communicate the value of our work.*** To build a healthy future, we all must make an extra effort this year to engage with the public over these exciting missions.



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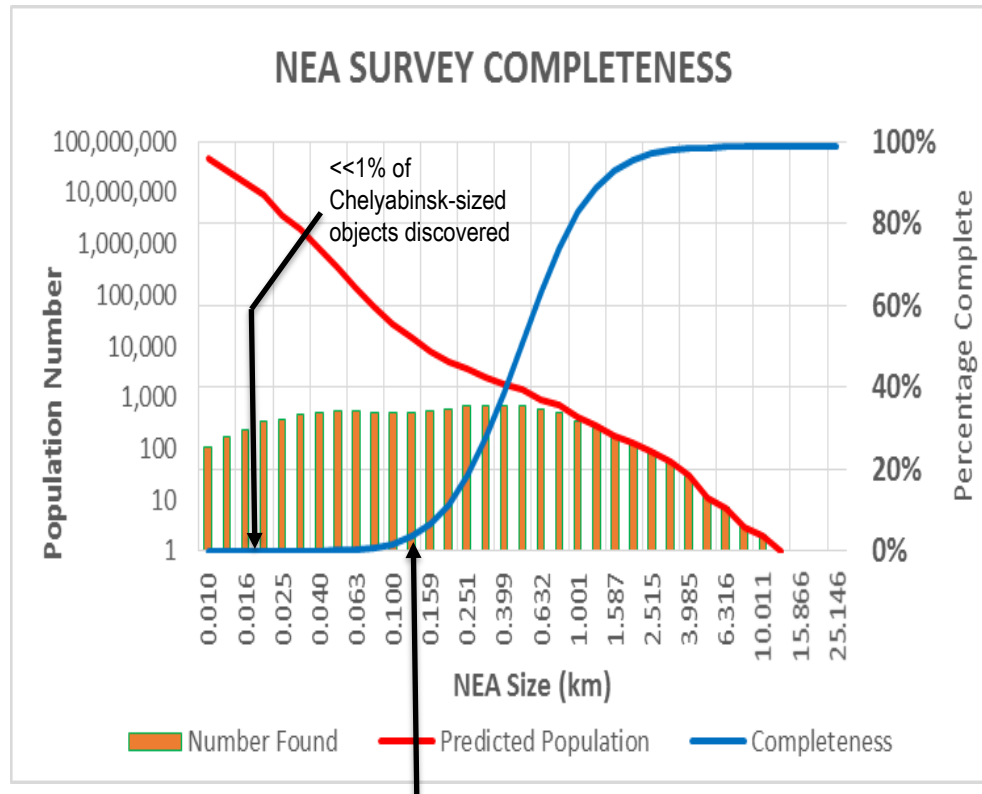
SBAG 12 Findings

Need for a Near-Earth Object Survey:

NASA's Asteroid Initiative comprises aspects of human exploration, planetary defense, resource utilization, and science related to near-Earth asteroids and comets. SBAG reiterates its previous findings that ***a space-based near-Earth object (NEO) survey telescope would be a foundational asset that would most efficiently achieve the goals of NASA's Asteroid Initiative in the shortest amount of time.*** Cross directorate support for a space-based asteroid survey is fully consistent with the Asteroid Initiative already established as an agency-wide goal.

Need for a Near-Earth Object Space-Based Survey

Planetary Science Subcommittee Finding, Sept. 2014



An advanced space-based survey optimized for finding and characterizing near-Earth objects (NEOs) serves **multiple Agency goals**, consistent with **NASA's Asteroid Initiative and specifically the Asteroid Grand Challenge**: “to find all asteroid threats to human populations and know what to do about them.” It is a foundational asset to:

- **Planetary Defense** – a space-based asset provides the fastest way to achieve the congressional direction of discovering potentially hazardous asteroids²
- **Human Exploration** – a space-based survey telescope is needed to greatly expand the catalog of accessible targets for human exploration³
- **Science** – PSD science goal: Explore and observe the objects in the solar system to understand how they formed and evolved⁴

George E. Brown Act¹: 90% of ≥140 m by 2020
 Current status: <1% of 140-m objects; 25-30% of >140-m objects
 Ground-based surveys not on schedule to meet congressional direction²

The PSS finds that the elevation of an NEO Space-Based Survey Mission to the level of an Agency priority, and the pursuit of its new start, are essential for the broadly needed advancement of NEO knowledge.

1 NASA Authorization Act of 2005, Section 321, cited as the “George E. Brown, Jr. Near-Earth Object Survey Act”; 2 Defending Planet Earth, NRC Report, National Academies Press, 2010; 3 Target NEO Workshop Report (2011) <http://targetneo.jhuapl.edu/archives/2011files/TargetNEOWorkshopReport.pdf>; 4 NASA Science Plan, 2014



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SBAG 12 Findings

Affirmation of the NAC Statement of Human Missions to NEOs in Their Native Orbits

The NASA Advisory Council (NAC) letter dated August 4, 2014 states that: “It must also be noted that ARM [Asteroid Redirect Mission] is not a substitute for a [human] mission to an asteroid in its native orbit, which appears to be possible at a lower launch energy than previously believed based on recent data^{2–4}. Such a long duration deep space mission would be a logical step toward the horizon goal of humans to Mars.” ***SBAG strongly supports this NAC statement and finds that a human mission to an asteroid in its native orbit has unique merits and value***, regardless of whether ARM is flown.

SBAG maintains a summary chart of human-accessible near-Earth asteroid (NEA) data, updated every few months, at:
http://www.lpi.usra.edu/sbag/science/NHATS_Accessible_NEAs_Summary.png



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SBAG 12 Findings

Asteroid Redirect Mission

SBAG appreciates NASA's efforts to engage and communicate with the science community about the Asteroid Redirect Mission (ARM). SBAG further recognizes that NASA's Asteroid Initiative has raised awareness and emphasized the importance of asteroids within NASA, to other U.S. Federal agencies, to the general public, and to our international partners.

Although SBAG has not endorsed either Option A or Option B, the SBAG ARM Special Action Team Report, generated at the request of NASA, provides information for the relative benefits of the two options from science, planetary defense, and resource utilization perspectives.

However, SBAG reiterates its concerns from the 11th SBAG meeting about the limited benefits of ARM for advancing asteroid science or furthering planetary defense strategies, and that limits in the current knowledge of near-Earth asteroids contribute to schedule and cost risks. ***SBAG supports continued engagement with the NASA ARM team as the concept is refined.***



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SBAG 12 Findings

Cadence of Discovery Missions

SBAG is encouraged by the release of the Discovery AO within 2014, a major step to achieving the strategy outlined in the Decadal Survey. The Discovery program has made important and fundamental contributions to planetary exploration, and is of crucial importance to the future scientific exploration of the Solar System. ***SBAG regards the Decadal Survey recommendation of a ≤ 24 month cadence as an essential guideline and notes that the selection of two missions from the current AO could provide a means to regain the Decadal Survey recommended average cadence of Discovery.***



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SBAG 12 Findings

Concern for the Minor Planet Center Status

The Minor Planet Center (MPC) is a unique and crucial facility for the small bodies community both within the United States and internationally. In addition to serving as the clearinghouse for all astrometric observations of asteroids and comets, the MPC also plays a central role in the chain of notification involving potential impactors.

SBAG is concerned about recent changes at the MPC, including the resignation of the director and the center's overall status and future, and urges NASA to review the situation as soon as possible. Such a review should be conducted in conjunction with the International Astronomical Union, the organization under which the MPC is chartered.



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SBAG 12 Findings

Support for the NEO Program Development Plan

The recent NASA Office of Inspector General (OIG) Audit Report, *NASA's Efforts to Identify Near-Earth Objects and Mitigate Hazards*, includes recommendations intended to improve NASA's efforts to discover, characterize, and mitigate near-Earth object threats, and NASA SMD's response outlines a general plan to make progress on the recommendations within the year. SBAG supports NASA's response to the OIG report and considers the recommended development of a strategic plan for the NEO Program a highly valuable activity. ***SBAG strongly supports the creation of a NASA Planetary Defense Coordination Office, a top recommendation of the 2010 NAC Task Force report.***



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SBAG 12 Findings

Concern for NASA Educational Efforts

Historically, NASA has taken a leading role in communicating its discoveries to the nation and in inspiring future scientists and engineers. ***SBAG is concerned about the erosion of NASA's educational efforts as evidenced by two recent events: the deletion of a \$4-million education component of the OSIRIS-REx mission, and the marginalization of the small, local programs*** that were at the core of the supplementary Education and Public Outreach (EPO) grants to Principal Investigators.

SBAG supports a reinstatement of these OSIRIS-REx education programs within NASA's new educational policies and approaches.

SBAG is concerned that the current SMD Science Education Cooperative Agreement Notice will not engage SMD scientists and will risk losing these valuable EPO activities.



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SBAG 12 Findings

Concern for Technology Development Efforts

While the funding for technology appears to be relatively flat, ***both exploration and planetary science technology development efforts are in a time of transition and significant changes have occurred that are potential causes for concern by SBAG.*** The Space Technology Mission Directorate (STMD) may have objectives for technology development counter to near-term infusion opportunities commensurate with standard (e.g. TMC0) risk tolerance. The coordination and identification of needs for exploration and planetary science missions requires constant and proactive coordination between the “mission customers” and STMD, in addition to directorate-specific resources to address the gaps. The relationships are maturing and appear to be improving, but it is unclear how technology coordination is occurring and whether appropriate resources are available for both coordination and funding identified technology gaps.



SBAG Goals Document Effort

- **January, 2015:** SBAG 12 – kick-off of effort
- **June, 2015:** SBAG 13 – first drafts from committees presented to the community for discussion
- **December, 2015:** draft Goals Document posted to the SBAG website for community review
- **January, 2016:** SBAG 14 – discussion of SBAG Goals Document
- **February, 2016:** Final SBAG Goals Document posted

*SBAG Goals Committees and Products:
<http://www.lpi.usra.edu/sbag/goals/>*

SBAG Goals Document

Lead: Nancy Chabot (APL)

March 9, 2015

The SBAG Goals document is currently in the process of being drafted by the committees listed below. Drafts of the document will be presented at the SBAG 13 meeting in June 2015. The complete document will be discussed at the SBAG 14 meeting in January 2016 and will be finalized soon afterwards.

Goal 1: Science

Lead: Tim Swindle (Univ. Arizona)
Kieran Carroll (Gedex)
Julie Castillo-Rogez (JPL)
Will Grundy (Lowell Observatory)
Emily Kramer (JPL)
Joe Nuth (NASA Goddard)
Carol Raymond (JPL)
Heather Smith (NASA Ames)

Goal 2: Planetary Defense

Lead: Tommy Grav (PSI)
James Arnold (NASA Ames)
Brent Barbee (NASA GSFC)
Steve Chesley (JPL)
Leviticus A. Lewis (FEMA)
Paul Miller (LLNL)
Angela Stickle (APL)
Tim Titus (USGS)

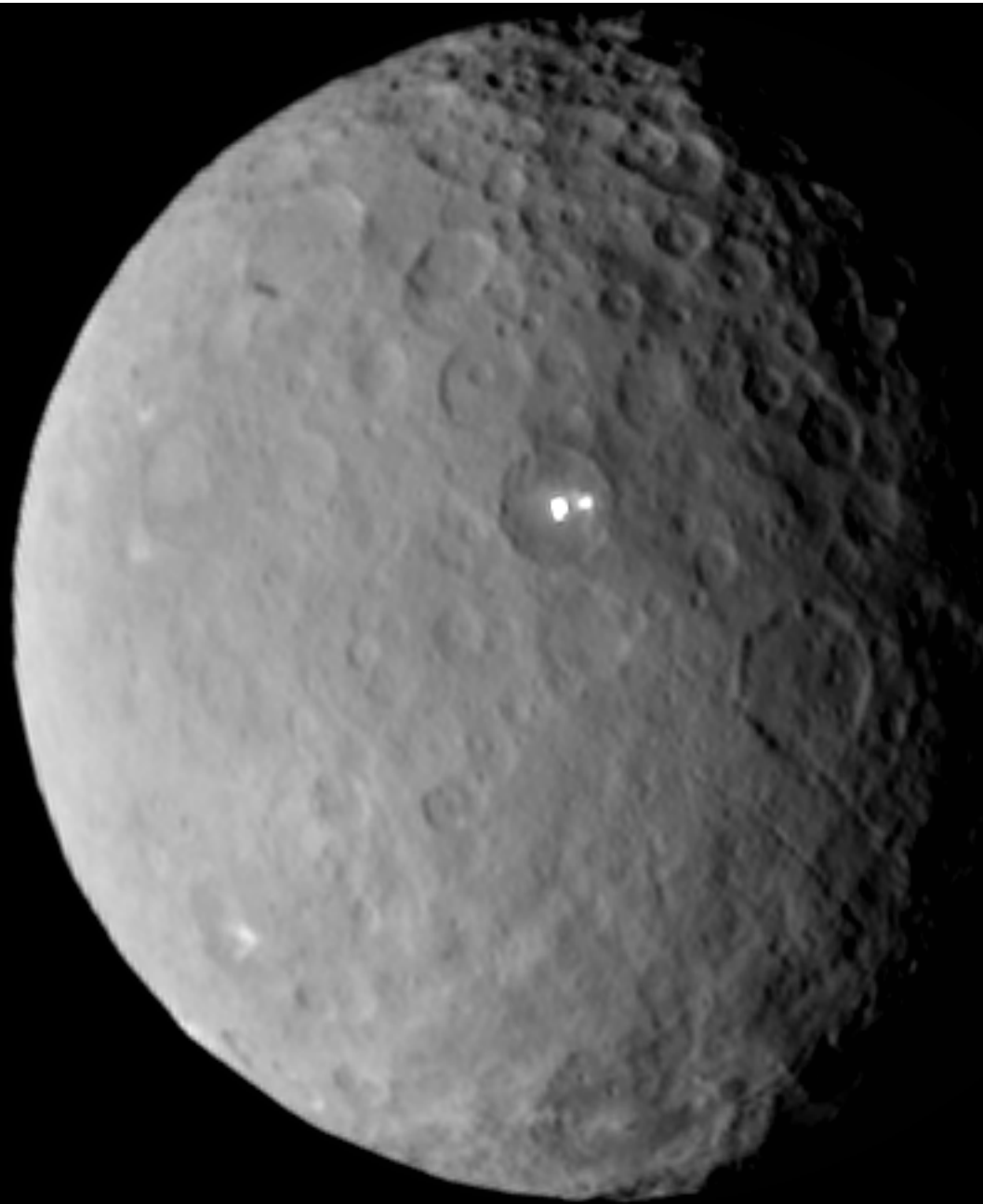
Goal 3: Human Exploration

Lead: Paul Abell (NASA JSC)
Brent Barbee (NASA GSFC)
Josh Hopkins (Lockheed Martin)
Sam Lawrence (ASU)
Stan Love (NASA JSC)
Carrie Nugent (IPAC)
Andy Rivkin (APL)
Mark Sykes (PSI)



Future SBAG Meetings:

- **June 29 – July 1, 2015:** 13th SBAG Meeting, Washington, DC
(June 30: Asteroid Day – “*Asteroid Day is a global awareness movement where people from around the world come together to learn about asteroids and what we can do to protect our planet, our families, communities, and future generations. Asteroid Day will be held on the anniversary of the 1908 Siberian Tunguska event, the largest asteroid impact on Earth in recent history.*”)
- **January 27-29, 2016:** 14th SBAG Meeting, Orlando, FL



March 6, 2015 –
*NASA's Dawn spacecraft
has become the first
mission to achieve orbit
around a dwarf planet.
The spacecraft was
approximately 38,000
miles (61,000 kilometers)
from Ceres when it was
captured by the dwarf
planet's gravity.*

National Aeronautics and Space Administration



After Nine Years
and Three Billion Miles

Pluto Awaits 2015



**NEW
HORIZONS**
A NASA New Frontiers Mission

www.nasa.gov

FIRST CONCEPT: 1989

MANY ITERATIONS OF A PLUTO RECON MISSION, UNTIL...

NEW HORIZONS CONCEPT SELECTED: NOV 29, 2001

FIRST MISSION IN "NEW FRONTIERS" CLASS

LAUNCH: JAN 19, 2006

ATLAS V ROCKET FROM CAPE CANAVERAL, FLORIDA

JUPITER FLYBY: FEB 28, 2007

GRAVITY ASSIST AND FLYBY REHEARSAL

CROSSED NEPTUNE'S ORBIT: AUG 25, 2014

EXACTLY 25 YEARS AFTER VOYAGER 2 VISITED NEPTUNE

PLUTO FLYBY

SPANS JAN -J ULY 2015

"BEST EVER" IMAGES
START IN MAY 2015

CLOSEST APPROACH
JULY 14, 2015

DATA DOWNLINKED
THROUGH LATE 2016



Accessible Near-Earth Asteroids (NEAs)



Goals of the Near-Earth Object Human Space Flight Accessible Targets Study (NHATS):

- Monitor the accessibility of the NEA population for exploration missions.
- Characterize the population of **accessible NEAs**.
- Rapidly notify observers so that crucial follow-up observations can be obtained.

NHATS data shown here
current as of: 2015-01-02

NHATS Web-site: <http://neo.jpl.nasa.gov/nhats/> NHATS Daily Updates: <https://lists.nasa.gov/mailman/listinfo/nhats>



Chart by: Brent W. Barbee (NASA/GSFC)

Selected NHATS Statistics:

Known NEAs:
11,963

NHATS NEAs:
1,327 (~11.0% of Known)

Mean H for Known NEAs:
21.919

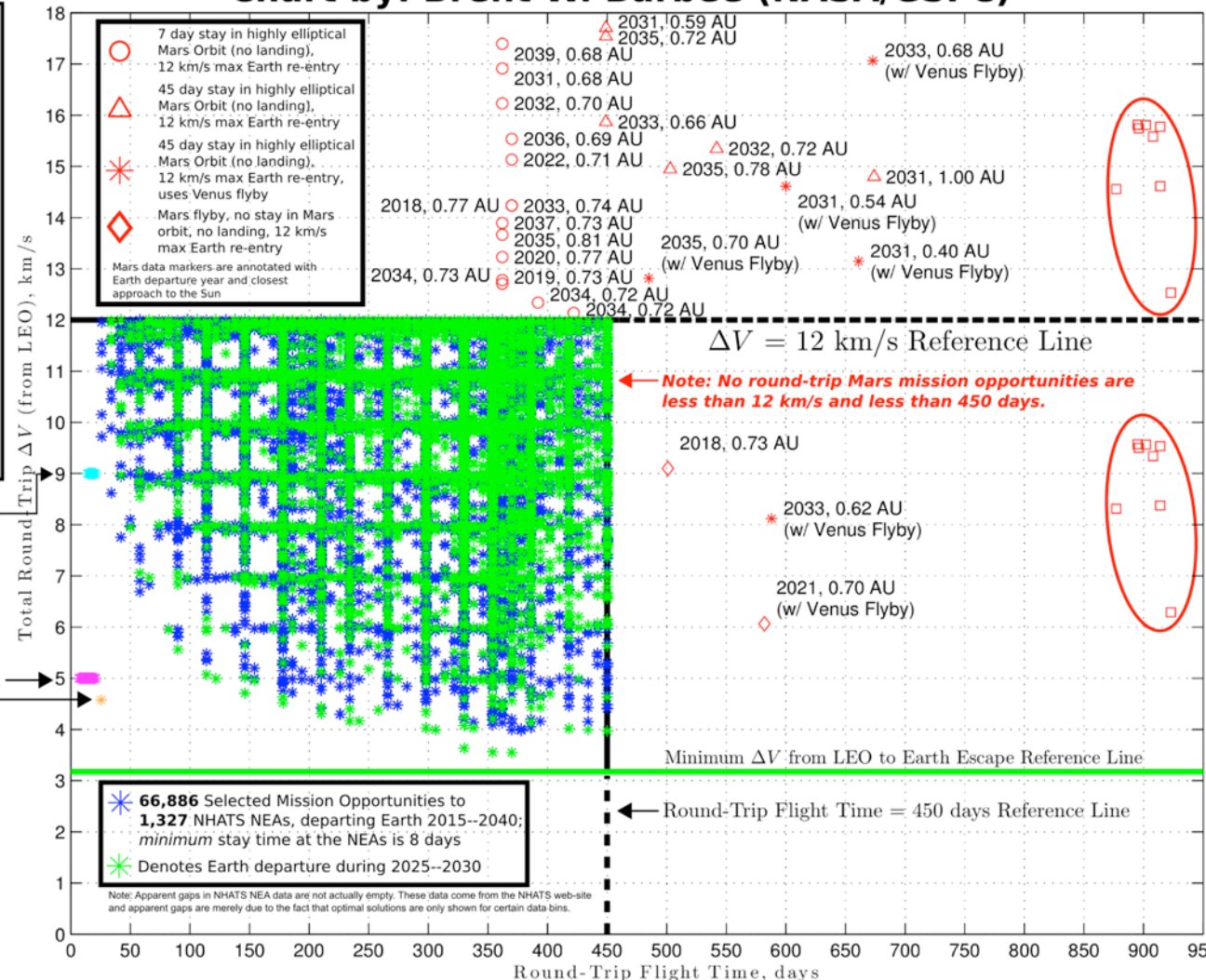
Mean H for NHATS NEAs:
24.878

NHATS NEAs by Orbit Type:
Atiras: 0% (0% of Atiras)
Atens: 23% (34% of Atens)
Apollos: 60% (12% of Apollos)
Amors: 17% (5% of Amors)

NHATS NEAs SMA (AU):
0.76, 1.16, 1.82
(Min, Mean, Max)

NHATS NEAs ECC:
0.01, 0.22, 0.45
(Min, Mean, Max)

NHATS NEAs INC (deg):
0.02, 5.19, 16.25
(Min, Mean, Max)



Round-Trip to Lunar Surface

Notes on Earth re-entry speed:
- Earth re-entry speed is approx. 11 km/s for lunar missions / ARRM
- Max Earth re-entry speed for NHATS is 12 km/s; many NHATS mission opportunities have < 12 km/s re-entry

Round-Trip to Low Lunar Orbit (no landing)

ARRM (human visitation of captured NEA in lunar DRO)

Mars Trajectory Data Sources:

7 day stay Mars data: Folta, D., Barbee, B. W., Englander, J., Vaughn, F., Lin, T. Y., "Optimal Round-Trip Trajectories for Short Duration Mars Missions," AAS/AIAA Paper AAS 13-808, August 2013
45 day stay Mars data: Folta, D., Barbee, B. W., Vaughn, F., "Analysis of Short Duration Round-Trip Mars Mission Opportunities During the Mid-2030s," Internal NASA/GSFC presentation, November 2011
500 day stay Mars data: Drake, B. G., ed. "Human Exploration of Mars Design Reference Architecture 5.0 Addendum," NASA/SP-2009-566-ADD, July 2009, http://www.nasa.gov/pdf/373667main_NASA-SP-2009-566-ADD.pdf *(w/ adjustments by B. W. Barbee for 12 km/s max Earth re-entry)
Mars flyby data: Adamo, D. R. analysis of http://inspirationmars.org/Written_Testimony_DTite_Nov2013.pdf and <http://www.youtube.com/watch?v=pu7Kk5s1k1k>, with input from Loucks, M.