Scenario 1
(modified Apophis)

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ASE-NEO Committee
Scenario 1

1) Scenario description
2) Additional background information
3) Issues and Questions
   a) Technical
   b) Institutional

Note: Current date = 22 January 2013
Association of Space Explorers

99942 Apophis

Earth Distance: 0.0156 AU
Sun Distance: 1.003 AU

Apr 13, 2029
99942 Apophis (2004 MN4)
Earth Impact Risk Summary

<table>
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<tr>
<th>Torino Scale (maximum)</th>
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<tr>
<td>Palermo Scale (maximum)</td>
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<tr>
<td>Palermo Scale (cumulative)</td>
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<td>Impact Probability (cumulative)</td>
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<tr>
<td>Number of Potential Impacts</td>
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</tr>
</tbody>
</table>

| V_{impact} | 12.59 km/s |
| V_{infinity} | 5.87 km/s |
| H | 19.7 |
| Diameter | 0.270 km |
| Mass | 2.7e+10 kg |
| Energy | 5.1e+02 MT |

Orbital Elements at Epoch 2455400.5 (2010-Jul-23.0) TDB
Reference: JPL 144 (heliocentric ecliptic J2000)

<table>
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<tr>
<th>Element</th>
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<th>Uncertainty (1-sigma)</th>
<th>Units</th>
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</table>

Orbit Determination Parameters

- # obs. used (total): 640
- # delay obs. used: 2
- # Doppler obs. used: 5
- data-arc span: 1395 days (3.82 yr)
- first obs. used: 2004-03-15
- last obs. used: 2008-01-09
- planetary ephem.: DE405
- SB-ephem. ephem.: SB-BIG16-1
- condition code: 0
- fit RMS: .48956
- data source: ORB
- producer: Steven R. Chesley
- solution date: 2009-Oct-23 11:54:34

Additional Information

Earth MOID = 8.12667E-5 AU
T_jup = 6.467
Figure 7. Predicted evolution of the uncertainty extent on the 2029 b-plane for 99942 Apophis. The four curves represent various observation scenarios. The contribution of the uncertainty in Yarkovsky modeling is included as described in the text. The vertical lines indicate the epoch of future Arecibo ranging opportunities. The gray region demarcates the time of a possible radio tracking mission, as described in the text.
Figure 10. Maximum possible impact probability for the 2036 potential impact, based on the uncertainties depicted in Fig. 7.
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2036 LOV & Risk Corridor
Impact Probability 1:250

120 Earth radii

200 Earth radii
Apophis-M risk corridor
Association of Space Explorers

$\Delta v$ requirement

\[ \log \Delta v \quad (m/s) \]

$\Delta v$ plot: NEO 2004 MN4

Along track positive $\Delta v$: thick line
Along track negative $\Delta v$: thin line

Impact date: 2036 Apr. 13, 08:51:40 UT

10 x Kinetic Impactor
1 metric ton @ 5 km/sec
1 x

12.2 days
@ 0.04 N
= 42,160 NS

Gravity Tractor
1 metric ton
1 day

Epoch of interception (yr)
Questions & Issues

Scenario 1

1) What criteria should guide the binary choice of deflecting the NEO ahead of or behind the Earth? (Minimum people along risk corridor?; minimum infrastructure value?; shortest distance?; lowest cost?; minimum time to completion?; etc.)

2) What considerations should guide the final targeted miss distance beyond the Earth’s surface? (Roche limit? i.e. potential breakup?; future close approach planning?; cost minimization?; etc.)
3) What tracking and/or analytical information is required from the IAWN for MPOG to perform its mission? What timing requirements (re planning) should be levied on IAWN to insure MPOG can address the mission planning issues?

4) Should there be levels of alerting or warning provided by IAWN, and if so, how should they be defined? E.g. preliminary mission planning advised as in Scenario#1?

5) What deflection techniques are available? What criterion should apply, if any, to the use of various techniques?
Questions & Issues

Scenario 1

6) Who deflects? What are the options for selection and the basis to be applied for such selection? Who makes the determination, and how? (MPOG, MAOG, Security Council, first on scene, maximum self-interest)

7) Who pays? How is cost determined and by what process is it approved and allocated?

8) Are there liability and/or other legal issues that must be addressed as MPOG moves ahead? What are they?
9) What oversight and/or control of the deflection planning and execution is required or appropriate?

10) Will national security (e.g. export control issues; ITAR & equivalent) preclude international cooperation in a deflection campaign? Can this be avoided?

11) How should MPOG be structured? Should this be integrated into ISECG in any way? Other existing structure?
Questions & Issues
Scenario 1

12) Should membership in MPOG be limited to the launch capable nations? Should nations specify which of their national space organizations will represent them in MPOG? Should MPOG representatives be able to commit their governments? If not, then in what higher forum should this occur?
Discussion