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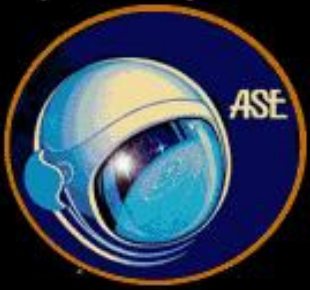
AT-14

49th Session, COPUOS/STSC

13 February 2012

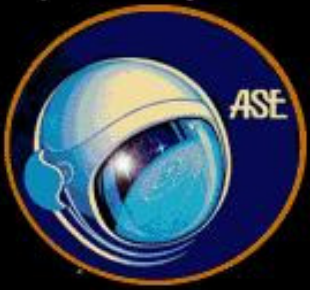
**Discussion on Asteroid
2011 AG5**

Rusty Schweickart
ASE-NEO Committee



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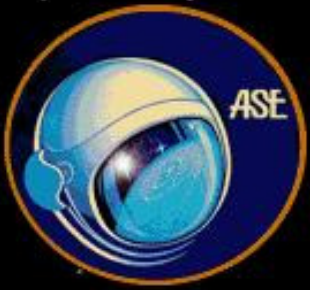
- ASE analysis of 2011 AG5 challenge
- Critical questions
- Analysis by other parties; NASA, NEOShield engineering partners (Surrey, Astrium, Deimos)
- ASE observations on engineering analyses
- Critical issues identification
- ASE Conclusions and Recommendations
- References



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AG5 is an impact threat; low, but significant:

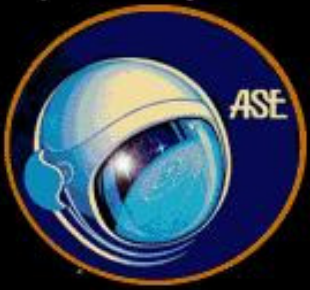
- 1) Impact probability = 1:625 (NEODyS, 1:588)
- 2) Dia. = 140 m; $M = 4.0e9$ kg; $E_{imp} = 100$ MT
- 3) Impact date = 5 Feb 2040; Precursor keyhole = 3 Feb 2023
- 4) Next apparition = ~ Sept. 2013
- 5) Of note: keyhole is very near current error ellipse centroid, (-0.15 sigma)
- 6) The primary challenge presented by AG5 is not (currently) its impact probability, but rather the time required to prevent impact, if indeed it is headed for the 2023 keyhole.



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AG5 may be an impact threat for which a deflection decision plan should be developed.

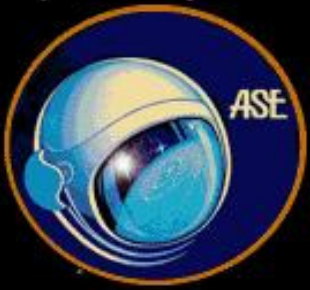
- 1) Decision date for a keyhole deflection is very soon, if not now.
- 2) If a keyhole deflection is ruled out as option, a direct deflection (if AG5 does pass through the keyhole; 1:625 probability) is marginally possible, at best.
- 3) IAWN & MPOG, if they existed, would now be advising MAOG on its options and the consequences.



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Observations and Recommendations

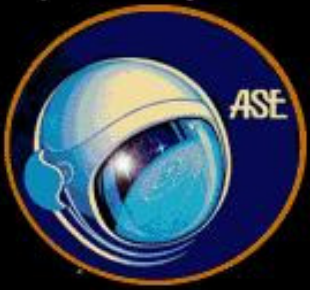
1. AG5 is an actual threat which emphasizes the need for implementation of the AT-14 recommendations to establish a NEO threat decision-making structure within COPUOS (i.e. IAWN, MPOG, MAOG).
2. AT-14, in lieu of the establishment of IAWN and MPOG, should form an ad hoc technical team to professionally address the issues identified in this analysis as well as additional relevant issues not yet considered.



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Observations and Recommendations

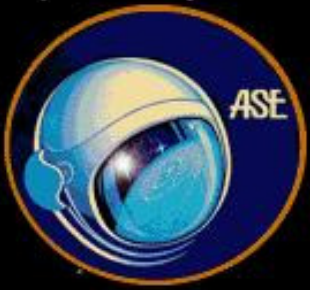
3. AT-14 should use the AG5 situation to accelerate and emphasize the immediate need for an operational NEO impact decision structure.
4. Other AG5's are coming, and we should be ready to deal with them.



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The three critical questions that need to be answered re the 2011 AG5 situation are:

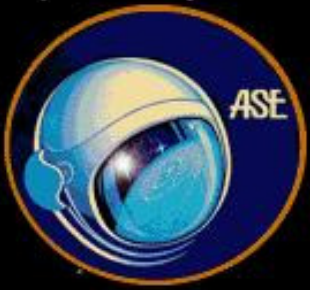
- 1) Assuming AG5 will otherwise pass through the 2023 keyhole can a decision to act now successfully prevent this from happening? (I.e. what is the lead time necessary for this specific keyhole deflection?)
- 2) Assuming AG5 will otherwise pass through the 2023 keyhole can a decision to act, delayed until after the next tracking apparition (Sept 2013), successfully prevent this from happening? (See a. above.)



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The three critical questions that need to be answered re the 2011 AG5 situation are:

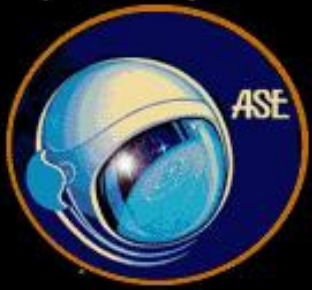
- 3) Assuming AG5 will pass through the 2023 keyhole if no action is taken to prevent it, can a successful deflection post-keyhole passage be successful?



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The answers to these three critical questions, based on the rough analysis performed by ASE are, respectively:

- 1) Yes, probably.
- 2) No, probably.
- 3) No, not if restricted to existing launch vehicle capability. Perhaps, if higher performance launch vehicles (e.g. Falcon Heavy) become available.

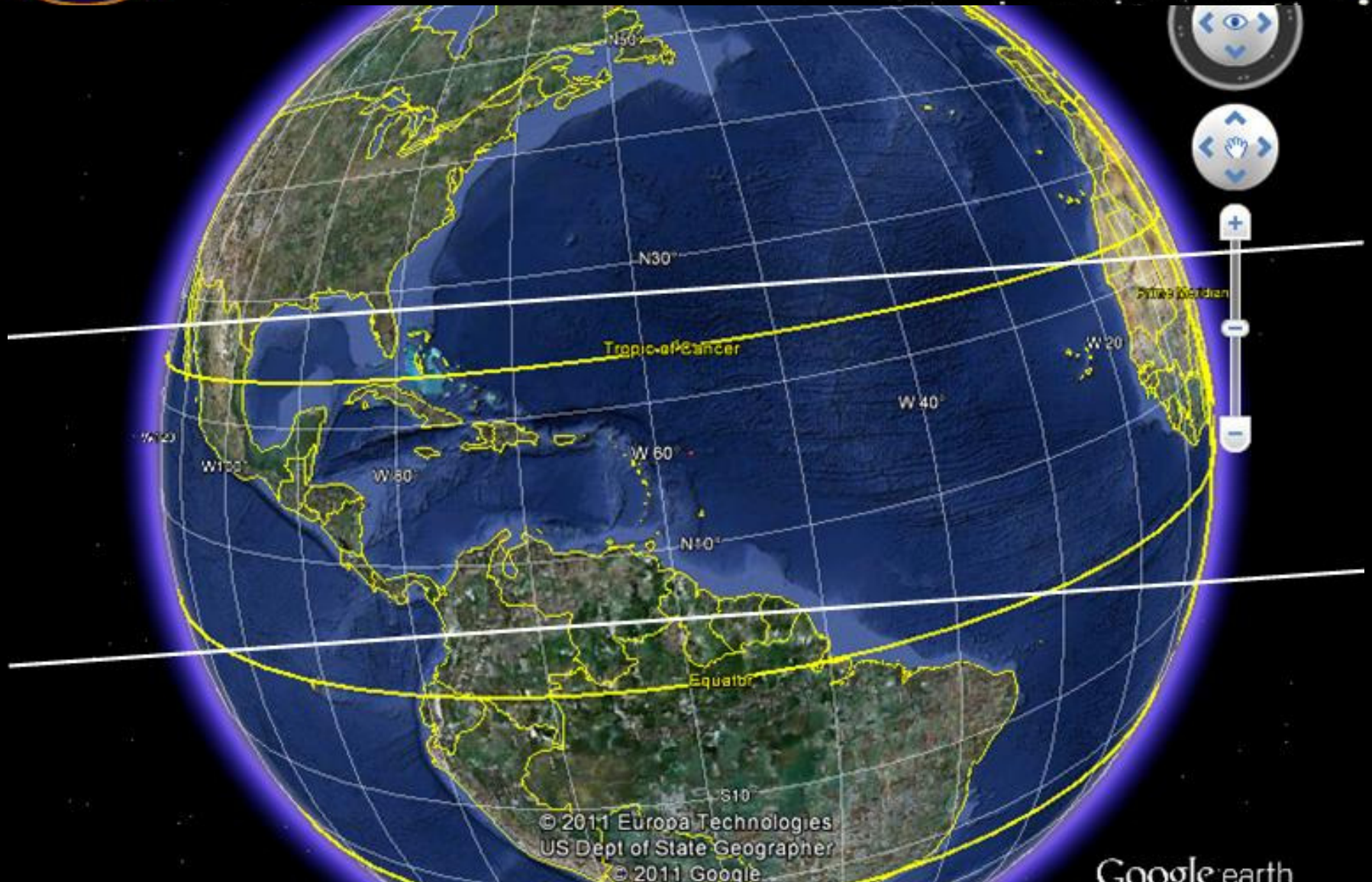


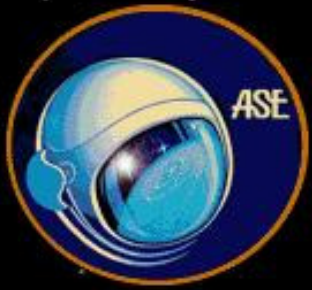
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The answers to these questions should not depend on a rough analysis by anyone but rather on a detailed and accurate analysis done cooperatively by professional experts.



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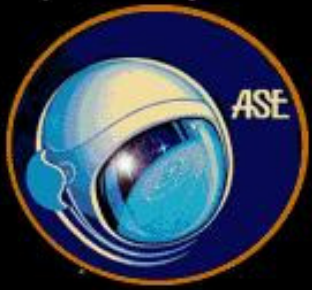




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Responses and Current Situation

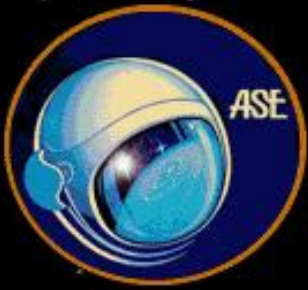
(NASA, NEOShield Surrey, Astrium, and Deimos)



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NASA Response (from NASA Administrator)

I assure you that 2011 AG5 is high on NASA's list of NEOs to monitor for impact hazard potential, and we take these duties very seriously. A transponder mission is not warranted at this time because of the opportunities for highly accurate ground-based observations in the near future. Based on these observations, a more informed assessment can then be made on the need for any type of mitigation. Even the 2015 apparition occurs seven years prior to the close "keyhole" passage. As a point of comparison, NASA's Deep Impact mission was conducted in six years from selection to impact under much less urgency, demonstrating the adequacy of a seven-year period for any necessary response.



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NEOShield/Astrium Analysis Results

(examined post-2023 options only, Falcon Heavy)

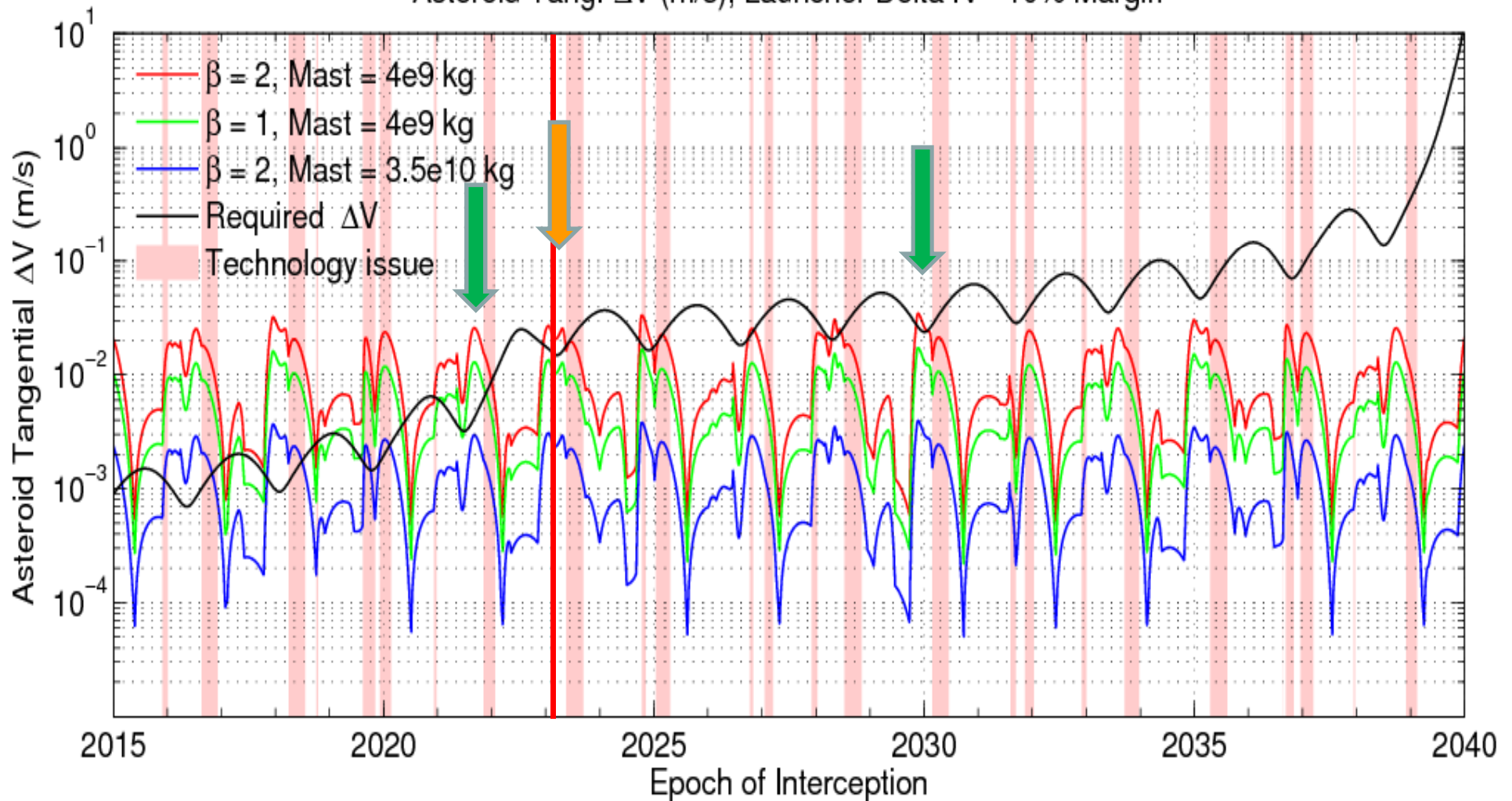
- 1) The mission options described (in the ASE analysis) can potentially be improved upon to impart greater change in the (NEO) semi-major axis.
- 2) Launches from 2026 to 2030 can achieve well in excess of 4Re asteroid deflection in 2040. This is achievable with both Falcon Heavy and Delta IV Heavy.
- 3) More detailed analysis on deflection modeling is warranted as this (analysis) is based on approximations.

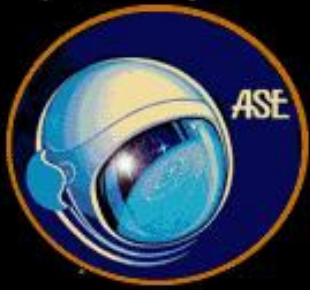


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NEOShield/Deimos Analysis Response (Delta IV Heavy)

Asteroid Tang. ΔV (m/s), Launcher Delta IV -10% Margin



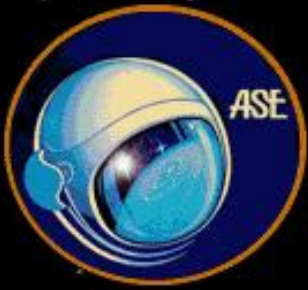


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NEOShield/Deimos Analysis Response

Table 4: Summary of solutions with asteroid deflection ΔV higher than 2 cm/s in period 2015-2040

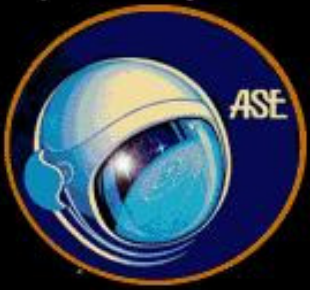
Departure date	Arrival Date	Transfer duration (days)	Departure C3 (km ² /s ²)	Departure declination (deg)	Spacecraft mass (kg)	Arrival relative velocity (km/s)	Arrival effective velocity (km/s)	Asteroid deflection ΔV (cm/s)	Deflection criteria met
21/09/2015	13/07/2016	296	4.40	-28.77	8698	11.93	5.83	2.53	Yes
25/10/2016	08/05/2018	560	20.93	12.06	6556	18.77	6.28	2.06	Yes
14/03/2017	15/12/2017	276	3.24	13.45	8872	11.81	7.26	3.22	Yes
08/07/2017	05/03/2018	240	16.88	-30.58	7027	8.36	7.23	2.54	Yes
23/10/2018	10/01/2020	444	12.30	5.98	7600	16.91	6.21	2.36	Yes
12/03/2019	04/09/2019	176	63.57	17.15	2975	18.27	14.16	2.11	Yes
22/10/2020	05/09/2021	318	4.50	-18.07	8684	13.70	5.94	2.58	Yes
14/02/2022	22/01/2023	342	2.44	5.67	8995	11.17	6.02	2.71	Yes
22/07/2022	22/04/2023	274	9.69	-33.62	7946	9.48	6.43	2.55	Yes
21/10/2023	22/02/2025	490	15.49	8.90	7197	17.75	6.24	2.25	Yes
15/03/2024	13/10/2024	212	24.62	16.14	6152	15.25	10.82	3.33	Yes
24/10/2025	25/10/2026	366	6.97	-3.94	8324	15.17	6.09	2.53	Yes
17/08/2027	10/06/2028	298	6.80	-25.85	8349	11.12	6.03	2.52	Yes
27/08/2027	16/01/2028	142	7.35	-18.51	8270	13.47	5.68	2.35	No
10/03/2028	07/05/2028	58	15.15	55.59	7239	12.97	8.46	3.06	Yes
20/10/2028	07/04/2030	534	18.71	10.94	6811	18.45	6.26	2.13	Yes
11/03/2029	20/11/2029	254	8.12	15.13	8162	12.89	8.44	3.45	Yes
26/10/2030	12/12/2031	412	10.08	3.41	7893	16.31	6.18	2.44	No



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Based on the latest analysis:

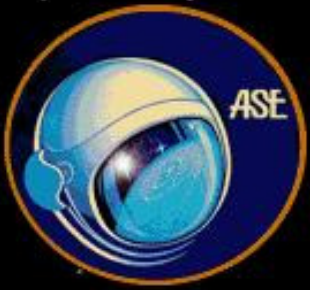
- 1) A deflection campaign delayed until after the 2023 close approach appears marginally possible if a decision to commit is made immediately thereafter. Slightly more conservative assumptions in several key variables would, however, eliminate this option. (e.g. a 12% underestimate of the NEO diameter, etc.)
- 2) A deflection campaign delayed until after the Sept 2013 tracking opportunity appears to be well within launch vehicle capability, provided a commit to the campaign is made immediately thereafter. Such commitment would be required with an impact probability well below 100%.



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Based on the latest analysis:

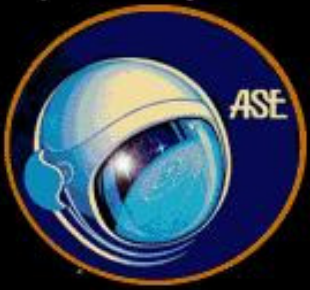
- 3) There appear to be three marginal deflection campaign opportunities if commitment is delayed till after the 2015 tracking apparition. These opportunities depend upon relatively optimistic assumptions and would have to be made with impact probabilities less than, but close to 100%.
- 4) A substantial number of critical issues, both technical and regarding matters of choice (e.g. level of risk acceptability) must be further investigated and refined to fully define the available decision options.



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Key issues requiring investigation:

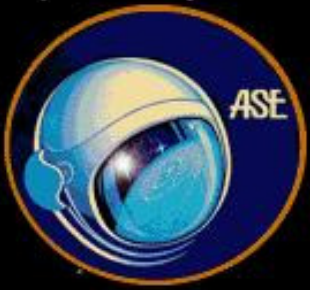
- 1) Deflection Campaign: All deflection options for 2011 AG5 require the use of a kinetic impactor. As identified by ESA during its Don Quijote planning, including a separate observer S/C is required to, inter alia, confirm KI success. A dual mission design is therefore required (i.e. deflection campaign) . While 7 years may be adequate for a single mission design this timeline may not be adequate for a realistic deflection campaign.
- 2) NEO mass uncertainty: All deflection options beyond the 2021 keyhole deflection would exceed LV capability if the asteroid diameter were as little as 25% above the nominal. Spectral data are critical for constraining this.



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Key issues requiring investigation:

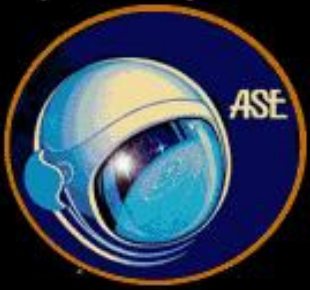
- 3) Terminal guidance limitations: Deimos identified 15 km/s as a potential limiting closing velocity. Compared with the US Deep Impact/Tempel 1 mission, the AG5 impact is significantly more challenging;
 - a) Cross sectional area; 1 vs. 1800
 - b) Closing velocity; 15 vs. 10.3 km/sec
 - c) Lighting; minimal vs. significant
- 4) Momentum multiplier: The analyses to date have assumed a value of 2.0. This may or may not be conservative. NEO spectra may help clarify this.



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Key issues requiring investigation:

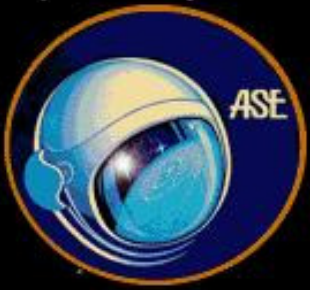
- 5) Additional, more robust deflection campaign alternatives such as multi-kinetic impacts and nuclear explosions, though likely to be expensive, need to be studied and evaluated.



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Conclusions

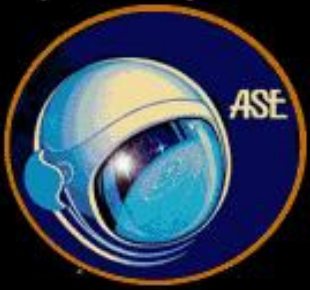
1. A deflection Decision Plan is required for 2011 AG5.
2. Priority research efforts are required on a series of key issues.
3. Coordination within the international community needs to be initiated immediately, including both technical and non-technical elements.



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Conclusions

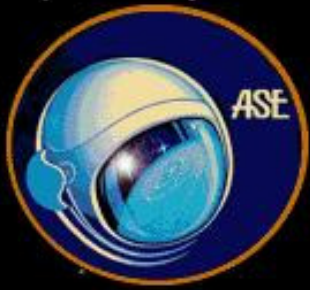
4. In the low probability case in which the impact of AG5 persists beyond the 2013 apparition, should a keyhole deflection campaign be foregone, for whatever reason, the international community may be faced with the difficult decision of choosing between an expensive multi-kinetic impactor or a nuclear explosive to prevent an impact should the NEO indeed pass through the keyhole.



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Recommendation

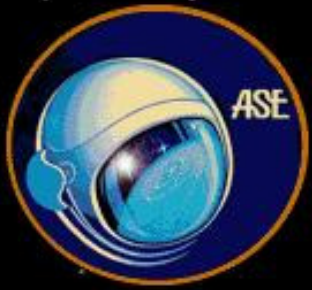
AT-14 should establish an ad-hoc 2011 AG5 evaluation team to collectively and immediately address all critical issues regarding this potential impact challenge.



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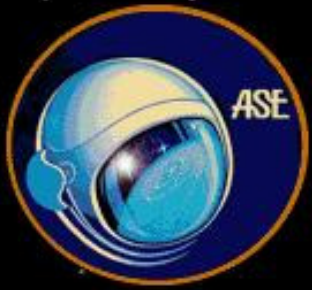
References

1. ASE analysis and transmittal
2. NASA analysis
3. NEOShield/Surrey Space Center analysis
4. NEOShield/Astrium analysis
5. NEOShield/Deimos analysis



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Discussion



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A Decision Program re
NEO threats, submitted to
the UN by the ASE and its
international Panel on
Asteroid Threat Mitigation

Presented to STSC in
February 09 & full
COPUOS in June 09.
Being coordinated within
COPUOS by Action Team-
14



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ASTEROID THREATS

A call for global response

A proposal for
an international
decision-making
program to protect
our planet from
Near Earth Object
impacts.

Dealing with the
Impact Hazard

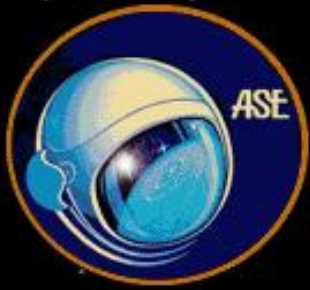
Toward a Decision-
Making Program for
Asteroid Threats

Recommendations
on a Decision-Making
Program for a
Global Response
to Asteroid Threats



September 25, 2008

ILLUSTRATION: DANIEL BERNA



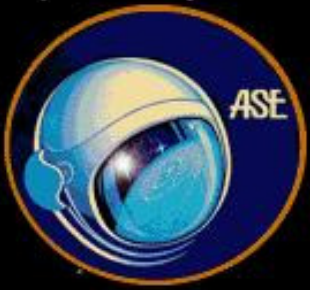
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Thomas Jones (USA)
Edward Lu (USA)
Dumitru Prunariu (Romania)
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Franklin Chang-Diaz (USA/Costa Rica)

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Key Recommendations Defined functional responsibilities

