

**9<sup>th</sup> IAA Planetary Defense Conference – PDC 2025  
5-9 May 2025, Stellenbosch, Cape Town, South Africa**

**IAA-PDC-25-01-130**

**Overall Results of the SMPAG Work Package on Mission Scenarios in  
Response to the 2025 Planetary Defense Conference Hypothetical Asteroid  
Impact Threat Scenario**

Juan L. Cano<sup>(1)</sup>, Brent W. Barbee<sup>(2)</sup>, Michael Khan<sup>(3)</sup>, Camilla Colombo<sup>(4)</sup>,  
Massimiliano Vasile<sup>(5)</sup>, Richard Moissl<sup>(6)</sup>, Detlef Koschny<sup>(7)</sup>

<sup>(1)</sup> ESA ESOC / Planetary Defence Office, Robert-Bosch-Straße 5, 64293, Darmstadt, Germany,  
[juan-luis.cano@esa.int](mailto:juan-luis.cano@esa.int)

<sup>(2)</sup> NASA/Goddard Space Flight Center, Code 595, 8800 Greenbelt Road, Greenbelt, MD, 20771,  
USA, 301-448-5681, [brent.w.barbee@nasa.gov](mailto:brent.w.barbee@nasa.gov)

<sup>(3)</sup> ESA ESOC / Mission Analysis Office, Robert-Bosch-Straße 5, 64293, Darmstadt, Germany,  
[michael.khan@esa.int](mailto:michael.khan@esa.int)

<sup>(4)</sup> Department of Aerospace Science and Technology, Politecnico di Milano, Via La Masa 34, 2016  
Milano, Italy, [camilla.colombo@polimi.it](mailto:camilla.colombo@polimi.it)

<sup>(5)</sup> Department of Mechanical & Aerospace Engineering, James Weir Building, 75 Montrose Street,  
University of Strathclyde, Glasgow, United Kingdom, [massimiliano.vasile@strath.ac.uk](mailto:massimiliano.vasile@strath.ac.uk)

<sup>(6)</sup> ESA ESOC / Planetary Defence Office, Robert-Bosch-Straße 5, 64293, Darmstadt, Germany,  
[richard.moissl@esa.int](mailto:richard.moissl@esa.int)

<sup>(7)</sup> Lunar and Planetary Exploration, TUM, Lise-Meitner-Str. 9, 85521 Ottobrunn, Germany,  
[detlef.koschny@tum.de](mailto:detlef.koschny@tum.de)

## **Abstract**

The members of the Space Mission Planning Advisory Group have performed an asteroid impact simulation exercise over a medium size asteroid with impact chances on 24 April 2041, in preparation for the 2025 Planetary Defense Conference. The exercise articulated on two different simulation periods lasting respectively two months and a half and four months. In the first period, Epoch 1, the asteroid impact probability grew from 1.6% to 10% and was played in real time. A preliminary assessment of the required actions that would need to be implemented and a set of recommendations were provided at a plenary SMPAG session held on 10 October 2024. Epoch 2 was simulated after the fast flyby of a reconnaissance mission by the asteroid in April 2028 that allowed refining the asteroid size, and impact location. An assessment of the decisions that were required and the feasible mission options was performed in order to facilitate a recommendation making by the SMPAG plenary. Mission options included kinetic impactors, ion-beam deflection and nuclear explosive devices.

*Keywords: Planetary Defense, Asteroid Deflection, Mission Analysis, Trajectory Design*

## **Introduction**

Members of the UN-endorsed Space Mission Planning Advisory Group (SMPAG) have participated in a hypothetical asteroid impact threat exercise in preparation for the 2025 Planetary Defense Conference (PDC2025). The exercise was articulated along two so-called injects. The first one, so called Epoch 1, started on 01 August 2024 and

lasted until mid-October with the drafting of a series of SMPAG recommendations for an international response to the threat represented by simulated asteroid 2024 PDC25. The second inject, so called Epoch 2, was released on 16 December 2024 with a reference date on 28 April 2028 and simulated in the subsequent months, with an updated series of recommendations produced by SMPAG for PDC2025.

During the first inject, several work packages were identified for coordination by different SMPAG members. ESA proposed to coordinate WP01, devoted to the definition of the possible mission scenarios. Those scenarios included reconnaissance options and deflection options.

The main contributors to this joint effort have been the delegations from NASA, ESA, ASI and UKSA. Plenary discussions were held on a weekly basis (on Fridays), allowing the different teams to present new results at each opportunity, whereas dedicated WP01 meetings were also performed, particularly on a weekly basis (on Wednesdays) for discussion during Epoch 2. Flyby and rendezvous options were considered for the reconnaissance missions, and impact and rendezvous options were considered for the deflection missions. Different launcher options and deflection options were studied (including kinetic impactor, nuclear explosive device (NED), and ion beam and laser beam deflection).

### **Epoch 1 simulation input**

Epoch 1 was carried out from 1 August to 10 October 2024 and assuming a real time evolution of events. At the first date of the exercise, IAWN released a communication declaring that asteroid 2024 PDC25, which was discovered on 5 June by the Catalina Sky Survey, had reached 1.6% probability for an impact with the Earth on 24 April 2041 [1]. The asteroid size was estimated to most likely be in the range of 90–160 m in diameter, but possibly in a larger range of 50–280 meters. An assessment of the possible impactor physical properties in that range of sizes was performed by NASA Ames Research Center in [2] as input for the computations performed in Epoch 1.

In early October, the impact probability had risen to 10% and a set of recommendations were expected from SMPAG by 10 October at the next meeting of the group with UNOOSA. Thanks to some simulations performed both by NASA and ESA [3] during Epoch 1, if the object was to impact the Earth in 2041, the impact probability would have reached 40% by the end of 2024 and 100% by August 2025.

### **Epoch 1 results on mission scenarios**

During the first inject, several work packages were identified and assumed for coordination by different SMPAG members and WP01 was devoted to the mission scenarios. Those scenarios included reconnaissance options and deflection options. ESA proposed to coordinate this work package and actually performed that task after agreement of all the parties.

Main contributors to this joint effort were the NASA's mission assessment team (including several US institutions) [4], ESA's mission analysis team, a team from Politecnico di Milano as part of the Italian Space Agency delegation [5] and a team

from University of Strathclyde as part of the UK Space Agency delegation. Mission re-tasking options are discussed in [6].

Plenary discussions were held on a weekly basis, allowing the different teams to present new results at each opportunity, whereas a few dedicated WP01 meetings were also performed. Flyby and rendezvous options were considered for the reconnaissance missions, and impact and rendezvous options were considered for the deflection missions. Different launcher options and deflection options were studied, including kinetic impactors, nuclear explosive devices (NED), and ion beam and laser beam deflection.

The overall program of activities in WP01 consisted of a first deep analysis of the problem, then a thorough discussion on mission design assumptions, followed by detailed assessments of the asteroid reconnaissance mission options and of the deflection options, and finally the formulation of a set of recommendations. During the weekly meetings the different teams presented their results until the recommendations were formulated and presented to the plenary for discussion.

Regarding the analysis the problem, the following facts were gathered:

- By August 2025 the knowledge on the impact to Earth will be mostly certain.
- The cost of any mission implementation can be phased into less costly design phases A/B, and more costly building phases C/D.
- Some highly relevant asteroid properties to planetary defense will remain largely uncertain unless a rendezvous reconnaissance mission is placed at the asteroid (e.g. size, mass, composition porosity, strength, etc.).
- Given the specific orbit conditions of the asteroid, early reduction of situational uncertainties by means of a flyby reconnaissance mission is essential to minimize the deflection requirements and thus the overall cost.
- Some interplanetary space missions currently in flight might be suitable, under certain conditions, for re-tasking of their mission to support an early asteroid characterization.
- Direct and accurate evaluation of the results of any deflection action will require that a rendezvous spacecraft is placed at the asteroid.
- The earlier a deflection action is implemented, the less demanding the reduction/elimination of the threat becomes (relevant effect in overall cost).
- The maximum deflection needed by a kinetic impact mission will be a full Earth chord, whereas half an Earth chord will be required by deflection options involving rendezvous.
- Selection of the best suited deflection options will not be possible earlier than the arrival of the flyby reconnaissance mission. This implies that before that moment, and given the range of asteroid physical properties, several mitigation options and designs will need to be considered.

Further to the above facts, the following main assumptions for Epoch 1 were discussed and agreed (other minor assumptions are not discussed here below):

- Impact is certain after August 2025.
- At least 3 years are needed to design, build and launch a spacecraft to perform an asteroid reconnaissance flyby. Of that, 1 year is devoted to phases A/B.

- At least 5 years are needed to design, build and launch a spacecraft to perform an asteroid reconnaissance rendezvous. Of that, 2 years are devoted to phases A/B.
- Given a high degree of mission reusability from past mission concepts, 4 years can be assumed to design, build and launch a spacecraft to perform an asteroid rendezvous reconnaissance mission.
- The upper limit for asteroid disruption in the deflection studies is 10% of the asteroid escape velocity.
- The lower limit for high-confidence asteroid robust disruption is 10 times the asteroid escape velocity.

Reconnaissance mission scenarios were considered to have the possibility of performing fast flybys to constraint the size of the object as early as possible, and then the implementation of rendezvous missions to characterize the object to a larger extent, and witness and measure the implementation of the mitigation efforts.

In the deflection mission analysis several methods were considered:

- Simple kinetic impactor (KI) and multiple kinetic impactor (MKI) deflection
- Ion beam deflection (IBD)
- Laser ablation deflection (LAD)
- Nuclear explosive device deflection (NED)

Transfer options were computed and deflections evaluated in terms of the assumed mission features and achieved deflection levels as a function of the asteroid mass and its physical properties (e.g. the beta parameter). These analyses led to the derivation of the number of launches and spacecraft needed in order to achieve the required deflection for each of the selected options. Taking all the above into account, the different teams produced a wealth of results for Epoch 1, most of which are discussed in these dedicated works [4], [5] and [6].

Those results were utilized to produce summary timelines where reconnaissance and deflection mission options were displayed, together with their proposed arrival features (either flyby, intercept or rendezvous) and their propulsion capabilities (either chemical or solar electric propulsion – SEP).

## **Epoch 1 recommendations**

Therefore, the coordination activities involved the discussion of mission goals and assumptions, the joined analysis of mission options, the definition of priorities for the actions to be taken, the approach for the crosschecking of results and the initial proposal of recommendations. The latter was based on the analysis of the possible mission options available and on the establishment of previous timelines for mission deployment. The main recommendations at the end of epoch 1 were:

1. Start, as soon as possible, the initial design phases (so-called phases A/B) of a fast flyby reconnaissance mission.
2. Consider re-tasking already flying spacecraft to perform an early reconnaissance of the target asteroid.
3. Start, as soon as possible, the initial design phases (phases A/B) of a solar electric propulsion rendezvous reconnaissance mission, independently of the implementation of an earlier flyby reconnaissance mission.

4. Start, as soon as possible, the initial design phases (phases A/B) of in-space mitigation missions, based on the following concepts, including the risk assessment on each option: kinetic impactor (deflection and disruption missions) and ion beam deflection.
5. Perform detailed simulations assessing the possibility to disrupt an asteroid by an impulse transfer.

Those recommendations were thoroughly discussed within SMPAG and included in a dedicated group document [7], that also counted with the active collaboration of the UNOOSA representative.

## **Epoch 2 simulation inputs and assumptions**

The second round of activities of the SMPAG asteroid impact threat exercise were kicked off on 16 December 2024, by means of a new IAWN notification with an effective date of 28 April 2028 [8], thus three years and nine months after the first one. At that moment, it was supposed that the planetary defense community had access to the results of a reconnaissance flyby mission developed in three years, launched at the end of September 2027, having a fast transfer to the asteroid and flying by it on 12 April 2028. By the time of the new IAWN communication the data from the flyby mission had been processed and had rendered the following main information:

- The region of possible impact locations for 2024 PDC25 was highly reduced, now extending 470 km across Angola and the Democratic Republic of the Congo.
- The asteroid size could be largely constraint to an equivalent diameter of 147–155 meters and an elongated shape, with an estimated axis ratio of around 2:1.
- The asteroid mass range derived from the size estimation and other assumptions on density and porosity was  $2.0\text{--}7.0 \times 10^9$  kg, and most likely between  $2.8\text{--}4.1 \times 10^9$  kg.
- The asteroid was confirmed to be of S type.

Thus, the most relevant update after the flyby of the reconnaissance spacecraft was the update on size and mass range, and the constraining of the impact area. No other fundamental physical properties could be determined from this mission. An assessment of the possible asteroid physical properties in the new range of sizes was provided by NASA Ames Research Center in [9] as input for the computations performed in Epoch 2. The summary of the relevant asteroid physical properties is provided in Table 1.

The improvement in the knowledge of the above-mentioned parameters implies that:

- The size and mass range in Epoch 2 is roughly equivalent to the one around the 75% percentile of the Epoch 1 mass range.
- There is 12-fold reduction in object size uncertainty and a 6-fold reduction in object mass uncertainty (both full range).
- The mass uncertainty is roughly 2.5 times the smallest mass value
- The resulting impact corridor implies that if a deflection was to be attempted in the Northward direction a total deflection in the b-plane of 7370 km would be required, whereas in the case of a Southward direction the deflection would need to be of 15352 km (including a margin of 150 km over the surface)

Table 1: Samples of the asteroid physical properties at the given percentiles, including values framing the 99.7% highest posterior density interval (HPDI) as derived in [9].

Point case	Mass (kg)	Diameter (m)	H Mag	Albedo	Density (kg/m <sup>3</sup> )	Porosity (%)	Strength (MPa)	a (m)	b (m)	c (m)
lowest	2.00E+09	147	21.42	0.221	1211	59.5%	0.2	115	118	235
-99.7 HPDI	2.09E+09	152	21.98	0.123	1128	59.6%	0.3	122	122	237
5 <sup>th</sup>	2.60E+09	149	22.16	0.109	1514	57.0%	0.3	123	116	230
25 <sup>th</sup>	3.31E+09	149	21.24	0.253	1902	40.2%	0.8	120	115	241
50 <sup>th</sup>	3.93E+09	150	21.60	0.179	2207	31.3%	1.0	119	117	244
75 <sup>th</sup>	4.59E+09	151	21.59	0.179	2540	24.4%	1.2	119	120	242
95 <sup>th</sup>	5.49E+09	152	21.58	0.178	2968	9.3%	4.2	121	124	236
+99.7 HPDI	6.41E+09	154	21.86	0.135	3372	6.2%	5.8	112	125	259
Highest	7.03E+09	155	22.28	0.090	3598	3.9%	5.5	126	126	234

Furthermore, given that the KI deflection method can only impart effects in the Southward deflection (SWD) direction, any deflection method could be employed in that direction, whereas the KI is excluded from the Northward deflection (NWD). It can also be mentioned that the NWD option imposes that the deflection path passes over lots of highly populated areas over Africa and Europe, whereas the SWD has less exposure to such situation and more to segments over large areas of water. This further means that for the SWD a partial deflection might be possible if thought of use, whereas in the NWD case this would be rather challenging, and it was completely disregarded.

Regarding the proposed recommendations from Epoch 1, the following were agreed to be assumed on them:

- Recommendation #1 on the fast flyby reconnaissance mission (FRM) was fully implemented, and the results of such mission are the inputs for this Epoch 2. In this case and knowing that the asteroid impact was confirmed at 100% in August 2025, the decision to go for phases C/D was taken and implemented in the two years between October 2025 and end of September 2027, with a launch at the end of that month. Fast flyby occurred on 12 April 2028.
- Recommendation #2 on the consideration of the re-tasking of already flying missions for a fast flyby, this was finally disregarded by means of the full implementation of the previous recommendation.
- Recommendation #3 on the development of phases A/B for a SEP rendezvous reconnaissance spacecraft (RRS) mission was implemented, and after the two years of the preliminary phases, a subsequent decision was made at the end of September 2026 to proceed with the implementation phases (C/D).
- Recommendation #4 on the development of phases A/B for in-space deflection missions was implemented and after the two years of the preliminary phases, a subsequent decision was made at the end of September 2026 to proceed with the implementation phases (C/D) even if the knowledge on the asteroid mass was still uncertain. So, the design had to be flexible enough to cope with the feedback provided by the fast flyby reconnaissance mission first and then by the rendezvous reconnaissance mission.

- Recommendation #5 on the detailed disruption simulations was implemented in the elapsed time.

## **Epoch 2 results on mission scenarios**

Coordination activities continued during Epoch 2 as in the previous period. Supplementing the Friday plenary meetings, WP01 meetings were firmly established every Wednesday, discharging the plenary from the presentation of the detailed mission scenarios results, which were treated in the dedicated WP01 meetings. First WP01 meetings concentrated on the analysis of the evolution of the scenario and the discussion on the assumptions to be taken for ulterior assessments.

Given that, under the same deflection conditions, the earlier the deflection attempt the more effect can be inflicted to the asteroid, and that the most effective actions are performed around the perihelion, special care was taken on trying to make use of the first perihelion after the arrival of the earliest rendezvous reconnaissance spacecraft in the summer of 2032. The next perihelia occur in: October 2032, December 2034, January 2037 and March 2039 in order of deflection preference.

When considering the KI mission options, it is remarked that this possibility could only be applied in the case a SWD was selected, which is by far the longest deflection path, but the less populated. Discussions on KI options were always having in consideration disruption limits towards total avoidance of disruption. A 10% of the asteroid escape velocity ( $V_{esc}$ ) was considered in general and in some cases a 4% in order to account for uncertainties in the beta parameter. Furthermore, given the fact that the earlier the deflection action the more effective, a Primary option was considered to launch KI missions before the arrival of the RRS, even if the uncertainty on asteroid mass will still be relevant at KI mission launch. The KI shall arrive sometime after the RRS arrival, e.g. by 4 months. Use of several KIs shall be performed in such a way that there is enough time for the environment around the asteroid to clear of debris and for the RRS to determine the degree of success and deflection of the previous impact. The mass of the spacecraft in the first batch of missions was optimized to avoid disruption of the weakest asteroid case (low mass and high beta). A second batch of KIs would be launched once the asteroid mass was determined in order to complete the deflection. A Backup option was also analyzed by assuming that all the KIs are manufactured once the mass of the asteroid was known and thus launching more that 2 years after the arrival of the RRS. Given that the KI spacecraft mass can be optimized to the needs in this case, the final results between the Primary and the Backup cases were comparable.

Regarding the IBD options, it shall be considered that this option typically requires long times to achieve the needed deflection and even several spacecraft acting at the same time. Obviously, the earlier the arrival of these spacecraft to the asteroid, the more effective the measure will be. Advantages of this option are the contactless interaction with the asteroid and the full control over the imparted deflection. The main dimensioning factors in this option are the available power for the ion thrusters, the spacecraft dry mass and the propellant mass (including both for the SEP transfer and for the ion-beam deflection). The last one is determined by the launch and transfer results. During the simulation, options were considered for full NWD, full SWD and partial SWD. The most effective option in this case is to try reaching the asteroid in

time to start deflection in the 2032 perihelion. This option was considered as baseline for the IBD case, assuming that the technological challenges of this concept (related to the manufacturing of the ion engines and the PPU) can be solved in due time. In most of the cases it was found that the NWD and the partial SWD could be achieved with between 1 and 2 spacecraft with a power level at 46 kW (making use of 3 pairs of ion engines).

For NED, the main assumption taken in the assessment of this option in Epoch 2 was the one of a carrier spacecraft that will rendezvous with asteroid boarding multiple free-flyer NED modules. In this manner a chain of impulses can be imparted to the asteroid around the optimal time and direction in a fully controlled manner. The NED yield was assumed at 100 kt and the number of NED modules was determined by the launch and transfer conditions. Full deflection was reached if the amount of boarded NEDs was larger than the number of modules needed as a function of the perihelion where the action could be implemented. NED could perform the full deflection of all asteroid mass and deflection distance cases in all the perihelia passes of 2032, 2034 and 2037, and with limitations on the full SWD in case the deflection is performed in 2039.

Taking all the above into account, the different teams produced a wealth of results for Epoch 2, most of which are presented in these dedicated works [4], [5] and [6]. Those results were discussed during the weekly meetings and many similarities were found among them, taking also into account that some of the discrepancies could be explained by slightly different assumptions. In summary, between 4 and 7 spacecraft would be needed to fully implement KI deflection in the Southward direction, plus an additional rendezvous reconnaissance spacecraft. For IBD it would be required to employ: 2-3 spacecraft for Northward deflection, 4-5 spacecraft for Southward deflection and 2 spacecraft for partial Southward deflection. Finally, a single NED carrier boarding multiple free-flyer charges would be enough to achieve deflection in any of the available perihelion passes.

Further to all the above considerations, the WP01 team members iterated and agreed during Epoch 2 the content of a mission interchange format file in MS Excel. This interchange file allowed to share among the teams the computed mission information by providing the relevant input parameters and the derived ones in order to achieve a certain reconnaissance or deflection goal/s.

Given all the mission data generated by the participating teams, mission timelines were generated including the mission design, implementation, transfer and in-situ operation times. Examples of such timelines are given in Figure 1 for the two KI scenarios, the Primary and the Backup. In these scenarios, the RRS is required in order to inform of the asteroid mass and keep track of the deflection efficiency of the kinetic impactors.

Further to the above, some deflection evolution figures were created in order to illustrate the effectiveness of each method along time. Figure 2 provides the deflection evolution timeline in the high mass asteroid case for a full SWD with KI spacecraft (and different beta) and for a partial SWD with IBD considering the four different launch opportunities considered in [4]. NEDs would be represented as almost vertical lines at the perihelion passes, as this method allows performing the full deflections in any of

those by means of the detonation of consecutive single NED. Similar figures were created for the low mass case and the 50% percentile mass case.

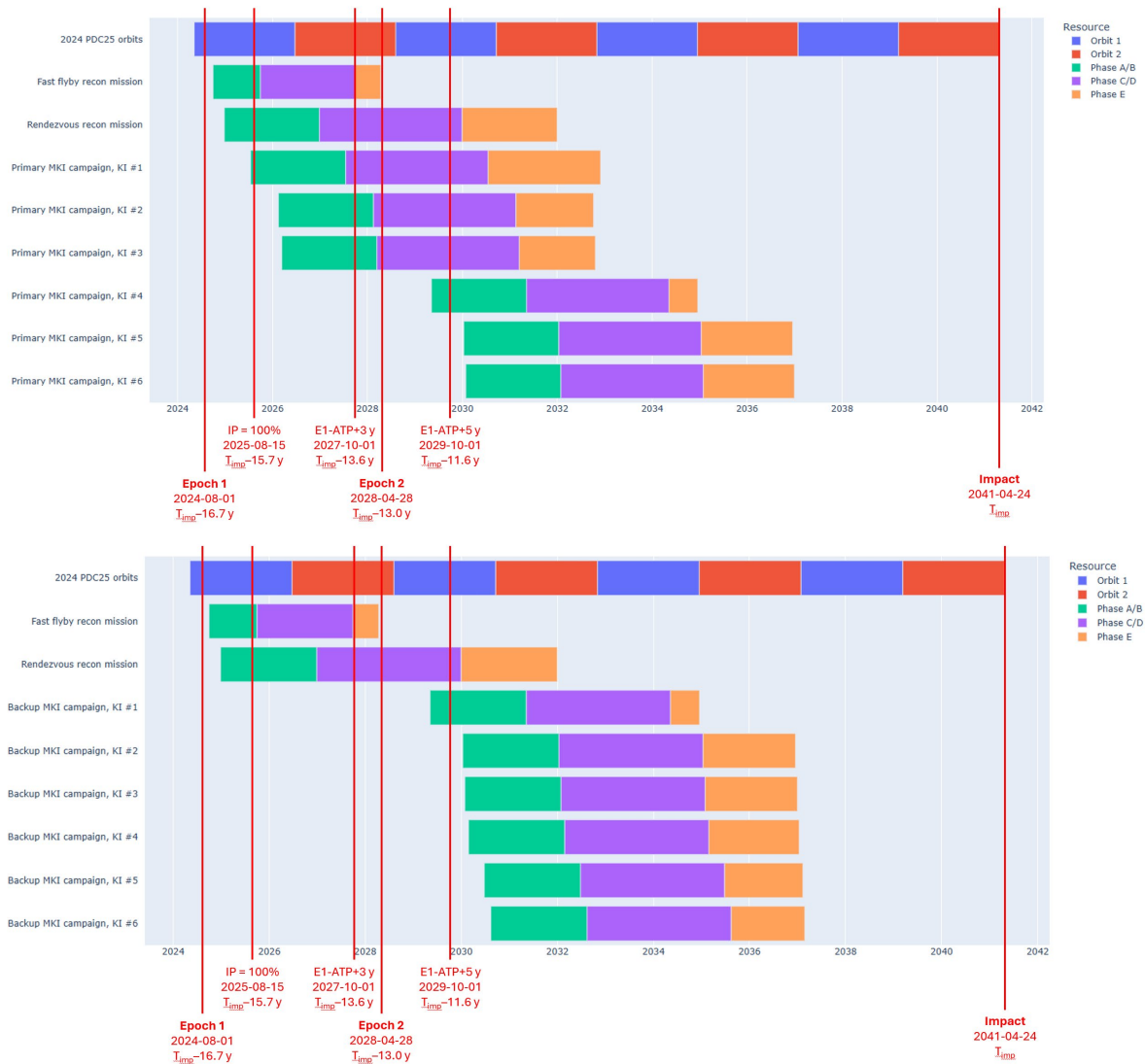


Figure 1: Timelines for the implementation of deflection by means of KI spacecraft missions in the Primary (above) and the Backup (bottom) options (missions derived from [4]). Depending on the asteroid mass it would be needed to make use of all or just some of those solutions

## Epoch 2 recommendations

Having all the above results in hand allowed WP01 participants to arrive to the following recommendations which were later elevated to discussion at the SMPAG plenary:

1. Decide whether the deflection will be northward or southward. In the first case, the deflection would be shorter, but over very populated areas, which would represent an added risk. Contrary to that, in the second case, the deflection would almost be double in size, but transiting over much less populated regions.
2. If southward deflection is selected, decide whether the partial deflection option is considered safe/acceptable, then decide whether partial deflection or total deflection will be the mission goal. Partial deflection would be a very reasonable

solution if demonstrated to not impact too negatively the Antarctic ice sheets or to not provoke threatening tsunamis on the nearby coasts.

3. Select a deflection mission type (KI, IBD or NED), complete its development, and deploy it. In this case, the selection process shall take into account the number of spacecraft required for each option, the number of launchers, their technological maturity and implementation feasibility and the political and cost implications.

Those recommendations were thoroughly discussed within the SMPAG plenary and prepared for presentation at the PDC2025 conference [10].

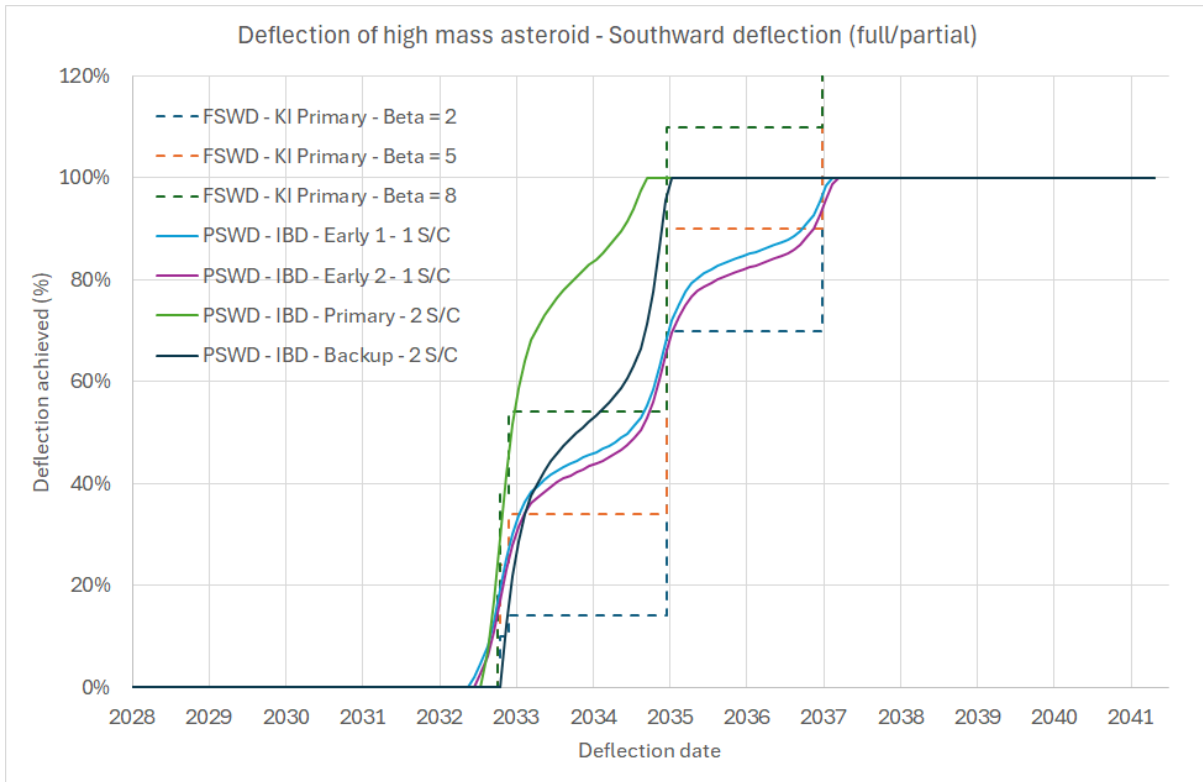


Figure 2: Deflection evolution timeline in the high mass asteroid case for a full SWD with KI spacecraft (and different beta values) and for a partial SWD with IBD considering four different launch options (missions derived from [4])

## Summary

The 2025 Planetary Defense Conference Hypothetical Asteroid Impact Threat Scenario has been the perfect occasion to showcase the capabilities of the SMPAG members in addressing the challenges of a very realistic impact scenario. The response of the “mission scenarios” group, under the so-called work package 1, has been successfully deployed over two very different epochs by intensely interacting over a prolonged period of time, agreeing on applicable assumptions, presenting and discussing detailed mission solutions, and finally proposing several recommendations for the consideration of the SMPAG plenary and evaluation by the UNOOSA Delegations.

During Epoch 1, and due to the high number of problem uncertainties, a wide breath of solutions needed to be proposed, including the development of both fast flyby and

rendezvous reconnaissance spacecraft, kinetic impactor, IBD and NED solutions. The initial study of the deflection options needed to cope with the high uncertainties in relevant parameters as the asteroid mass and the asteroid response to collision and close detonation interactions.

In Epoch 2, and thanks to the knowledge provided by the fast flyby reconnaissance spacecraft, the mass of the asteroid could be constrained to a point where the number of solutions could be substantially limited, still relying on KI, IBD and NED options. Furthermore, given the improvement in the knowledge of the impact region, Northbound and Southbound solutions were investigated. The improvement in knowledge was not enough to determine the response of the asteroid to spacecraft collisions, factor that was addressed by proposing different KI strategies compatible with the avoidance to accidentally disrupt the asteroid. Minimum number of spacecraft and launches were derived for each of the deflection scenarios. Finally, recommendations were proposed in terms of decision-making on the deflection direction, the possibility to use southward partial deflection and the final deflection technology to employ. Those are the decision elements that are to be addressed by the UNOOSA Delegates, together with cost, risk, technology maturity and political factors, in order to complete a satisfactory response to the threat of this simulated impacting asteroid.

## References

- [1] IAWN Potential Asteroid Impact Notification – Hypothetical Simulation, *Potential for Impact of Near-Earth Asteroid 2024 PDC25*, 2024-08-01.
- [2] L. Wheeler, et al., *Impact Risk Assessment: PDC25 Hypothetical Asteroid Impact Exercise Epoch 1 – Initial Threat Discovery & SMPAG Notification*, slide deck released on 2024-08-01
- [3] L. Faggioli et al., *ESA NEOCC: Impact Assessment of 2024 PDC25*, presented at this same Planetary Defense Conference, 5-9 May 2025.
- [4] B. Barbee, J. Atchison, R. Bull, M. Burkey, W. Caldwell, P. Chodas, J. Dotson, D. Farnocchia, K. Fast, L. Johnson, K. Kumamoto, J. Lyzhoft, D. Mazanek, R. Park, J. Pearl, C. Plesko, I. Santistevan, M. Vavrina, *NASA Analysis of Space Mission Options for the 2025 Planetary Defense Conference Hypothetical Asteroid Impact Threat Scenario*, presented at this same Planetary Defense Conference, 5-9 May 2025.
- [5] S. Franzese, E. Basile, E. M., Polli, P. Vasiliki, M. Castronuovo, *Analysis of Asteroid Deflection Mission Options for the 2025 Planetary Defense Conference Hypothetical Asteroid Impact Threat Scenario by the Italian Space Agency delegation at SMPAG*, presented at this same Planetary Defense Conference, 5-9 May 2025.
- [6] J. Atchison et al., *Retasking In-flight Spacecraft for Rapid Response Reconnaissance in Planetary Defense Exercises*, presented at this same Planetary Defense Conference, 5-9 May 2025.
- [7] SMPAG, *SMPAG hypothetical Near-Earth Asteroid “2024 PDC25” impact exercise*, SMPAG-RP-006, issue 1.1, 29/10/2024.
- [8] IAWN Potential Asteroid Impact Notification – Hypothetical Simulation, *Updated potential for impact of Near-Earth Asteroid 2024 PDC25 using data from reconnaissance spacecraft flyby*, 2024-12-16.

- [9] J. Dotson, L. Wheeler, D. Farnocchia, *Impactor Physical Properties: 2024 PDC25 Hypothetical Asteroid Impact Exercise Epoch 2 – Post Flyby Reconnaissance*, slide deck released on 2024-12-16.
- [10] D. Koschny et al., *The international response of space agencies to the PDC 2025 exercise – the ‘SMPAG exercise’ – lessons learned*, presented at this same Planetary Defense Conference, 5-9 May 2025.