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RESULTS FROM THE EU-ESA WORKSHOP ON NEO IMMINENT IMPACTORS WARNING COORDINATION

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ABSTRACT

ESA's Planetary Defence Office (PDO) organised in December 2022 the EU-ESA Workshop on Near-Earth Object (NEO) Imminent Impactors Warning Coordination at ESOC, Germany. The workshop explored the possibilities of increasing the networking of actors involved in the process of discovering, acknowledging, tracking and observing NEO imminent impactors. Such goal shall ensure that the imminent impactor relevant information reaches all possible interested parties. The workshop was organised around four sessions: new developments and updates to imminent impactor services, observatories and observation networks for imminent impactors, imminent impactor observation opportunities by spacecraft and fireball networks and other sensing capabilities. In addition to the invited talks, ample time was left for discussion among the experts and meeting attendees. This paper presents a summary of the discussions held at the workshop.

INTRODUCTION

The EU-ESA Workshop on NEO Imminent Impactors Warning Coordination[1] has been the first action implemented within one of the tasks entrusted by the European Union (EU) to ESA within their SSA component, NEO subcomponent. In that task, ESA was requested to promote the networking of EU member state facilities and

[1] https://indico.esa.int/event/422

research centres in the NEO field by organising a yearly international event on near-Earth objects.
Building up on the recent occurrence of the impact of 2022 EB5 on 11 March 2022[2] and the impact of 2022 WJ1 on 19 November 2022[3], EU and ESA expected to increase the level of coordination and cooperation between all those actors, which include asteroid discoverers and observers, NEOCP[4] object analysts, spacecraft operators and fireball network operators. In the period between the workshop and the Planetary Defence Conference another event occurred, the one associated to object 2023 CX1 that happened on 13 February 2023[5]. A list of all the currently known past impactors is provided in Figure 1.
The workshop has helped in bringing together several different communities to increase the level of networking between all the relevant stakeholders in the field. Representatives from ESA, the European Commission (EC), NASA, JPL, the main NEO survey institutions, several NEO research centres, and several satellite operators and fireball network operators attended the meeting.

SESSIONS SUMMARY

The workshop was articulated along four main sessions:
1. New developments and updates to imminent impactor services
2. Observatories and observation networks for imminent impactors
3. Imminent impactor observation opportunities by spacecraft
4. Fireball networks and other sensing capabilities

In the first session, the presentations elaborated on the recent evolutions in the Minor Planet Center[6] (MPC) processing system and on the status of the imminent impactor systems currently operating at NASA (Scout[7]), ESA (Meerkat) and NEODyS (NEOScan[8]). In addition to those, a theoretical presentation on resonant returns and a presentation on a recent rapid response exercise within the EU NEOROCKS[9] project were provided. The session was closed by a talk on the discovery of the fifth ever identified impactor, 2022 EB5, by its discoverer.
Session 2 focused on the observational aspects of the imminent impactors, with talks provided on the performances of the main survey systems: Pan-STARRS[10], Catalina Sky Survey[11] (CSS) and ATLAS[12]. Further to that, ESA's PDO observers presented the efforts done at the NEO Coordination Centre[13] (NEOCC) to operate a network of telescopes to follow up relevant NEOs and a comparative study on the performances of the future ESA survey system based on the Flyeye telescope. Finally, a presentation was provided on the status of construction of the Vera Rubin

[2] https://neo.ssa.esa.int/-/fifth-notch-for-planetary-defenders
[3] https://neo.ssa.esa.int/-/sixth-meteoroid-detected-prior-to-impact
[4] https://www.minorplanetcenter.net/iau/NEO/toconfirm_tabular.html
[5] https://neo.ssa.esa.int/-/new-imminent-impactor-found-by-european-astronomer
[6] https://www.minorplanetcenter.net/
[7] https://cneos.jpl.nasa.gov/scout/
[8] https://newton.spacedys.com/neodys/NEOScan/
[9] https://www.neorocks.eu/
[10] http://legacy.ifa.hawaii.edu/research/Pan-STARRS.shtml
[11] https://catalina.lpl.arizona.edu/
[12] https://atlas.fallingstar.com/
[13] https://neo.ssa.esa.int/

observatory[14] and the expected performance of its Legacy Survey of Space and Time (LSST) regarding imminent impactors. The performances of the recently deployed NEO observation priority list services by the CSS, NEOfixer[15], and by NEODyS[16] were also provided.

The third session dealt with the assessment of the observation of impactors from space in their atmospheric phase. A presentation from the currently operating GOES geostationary lightning mapper [17] (GLM) was provided, complemented by a presentation of the expected performances of the Meteosat Third Generation [18] (MTG) lightning imager (LI), which, by chance, was launched in that same date[19]. A presentation by NASA's Planetary Defence Coordination Office [20] activities was provided, followed by a talk about results on the detection of weak meteoroids by US government sensors.

Finally, the fourth session focused on the description of the status of some international fireball detection programs and networks, as the ones deployed by the International Meteor Organisation[21] (IMO) and the AllSky7 network[22]. Further to that, the application of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) [23] network of infrasound sensors to meteor detection was presented, followed by a talk about ESA's NEMO monitoring system developed by University of Oldenburg.

After each of the sessions a dedicated discussion slot was programmed in order to allow reviewing the provided information in the talks and, particularly, collecting ideas for possible ways to improve the response of the related systems and discussing them. Those are presented in the next section.

No.	Object designation	Diameter in m	Impact date/time in UTC	Impact velocity in km/s	Estimated energy in Mt
1	2023CX1	1.0*	2023-02-13 02:59:00	14.02	3.41E-5
2	2022WJ1	0.7*	2022-11-19 08:27:00	13.96	9.16E-6
3	2022EB5	1.9*	2022-03-11 21:22:00	18.54	2.96E-4
4	2019MO	5*	2019-06-22 21:30:00	16.35	3.82E-3
5	2018LA	2.8*	2018-06-02 16:44:00	16.98	8.90E-4
6	2014AA	2.3*	2014-01-02 02:30:00	11.77	2.44E-4
7	2008TC3	3*	2008-10-07 02:45:00	12.40	6.77E-4

Figure 1: List of impacted objects observed prior to entry into Earth's atmosphere as provided in ESA's NEOCC web portal[24]

[14] https://www.lsst.org/
[15] https://neofixer.arizona.edu/
[16] https://newton.spacedys.com/neodys/index.php?pc=10.0
[17] https://neo-bolide.ndc.nasa.gov/
[18] https://www.eumetsat.int/meteosat-third-generation
[19] https://www.eumetsat.int/launch-success-mtg-i1
[20] https://www.nasa.gov/planetarydefense/
[21] https://www.imo.net/
[22] https://www.allsky7.net/
[23] https://www.ctbto.org/
[24] https://neo.ssa.esa.int/past-impactors

DISCUSSIONS SUMMARY

During the discussion associated to the first session about new developments and updates to imminent impactor services, following points were highlighted:

- A similarity was established with the case of the currently operating gamma ray burst (GRB) warning network, which has been very successful in tracking those events in the last 20 years. It was felt that the imminent impactors warning network is already very much in line with the performances of that other system.
- NEOROCKS representatives highlighted the role of this EU funded project in exercising for the first time a quasi-fully-automated process to enabling the physical characterisation of an imminent impactor[25].
- The importance of having accurate orbits to enable the observation of NEO physical properties was highlighted.
- Having immediate notification / warning applications on mobile phones, were identified as potentially very useful tools. This technology is currently being used by ESA's Meerkat system and was also used in the mentioned NEOROCKS exercise.
- The lack of telescopes fully devoted to observation of physical properties was identified as a source of risk to the analysis of imminent impactors with warning times larger than a few days. The need to have dedicated means for these purposes was clearly identified.
- MPC commented on the current implementation being performed at the centre to increase the automation of the treatment of NEOCP objects.
- It was recognised that there is a potential competing interest between the astrometric community and the physical properties observers. The former would prefer to keep the objects in the NEOCP as long as possible to foster more observations from the astrometric community and quicker, whereas the latter would prefer a fast processing of the NEOCP object into formal designation. The fact that MPC is moving to a database model accessible in real time should mitigate that situation.
- It is recognised and stressed the difficulty that observing imminent impactors represents, moving at high velocities in the sky. It is recommended that observers wanting to efficiently observe imminent impactors exercise their processes enough to be prepared for future events. Precise timing calibrations shall be implemented as recently exercised in the IAWN campaigns targeted at asteroids 2019 XS (in November 2021)[26] and 2005 LW3 (in November 2022)[27].
- It is also recognised that the above problem is very much associated to very small objects that do not typically represent a threat. For larger objects, longer warning times should be typically available (at least in the cases where the object is coming from the night side of the Earth) and the above problem should be somehow mitigated.
- Standardisation and automated commanding of telescopes might help in automating the whole follow-up process as well as the observations to determine the physical properties. Work is still needed to fully automatise this

[25] https://www.tng.iac.es/news/2022/04/08/a-rapid-response-system-experiment-performed-at-tng-within-neorocks-project/
[26] https://iawn.net/obscamp/2019XS
[27] https://iawn.net/obscamp/2005LW3

process.

- Automation of observations would already improve the process substantially, even if the astrometry data reduction would need to still be done manually.
- A distinction between very close imminent impactors and imminent impactors with a few days warning time was made. In the former case there would be no possibilities to obtain physical properties observations, whereas in the later such goal would be possible.
- Small telescopes (e.g. 60-70 cm in diameter) can still be used to determine rotation, taxonomy and colours, without the need to call for larger telescopes.
- A standardisation of the warning message among all the systems could be helpful for the observers. Still, observers have the possibility to use the existing APIs (as the ones provided by Scout) to make use of the available information.
- When asked in the forum whether there was any piece of information required in addition to what is already available from the warning systems, no further information was identified as needed by the workshop group.

Regarding the second session centred on observatories and observation networks for imminent impactors, these items were discussed:

- Observations close to the galactic plane shall take into account the actual shape of the galaxy, which for example is provided by the Gaia star density map, which counts the number of stars per square arcmin.
- Alternatively, subtraction algorithms have proven to be very effective in allowing observations in the galactic plane.
- Another relevant aspect identified was the need to avoid losing objects after having been discovered. So, enough resources should be employed to constraint the orbits of the discovered objects, particularly the ones contained in any of the existing risk lists.
- CSS has found in the past that immediate follow-up results in great advantage for continuing observations in the next days.
- LSST will be covering the full sky every three nights, so many of the follow-up could be done through normal operation. However, there will always be objects that will need particular attention.
- Bill Gray's SatID tool[28] is used by several of the survey systems to rule out the possibility of an object being an artificial satellite.
- Regarding the possibility of making stereoscopic observation of close approachers, ATLAS has successfully performed some observations of the same object from two telescopes, but there is always the trade-off of whether it is actually more useful to have the two telescopes observing different targets.

In what regards the third session, which was focused on imminent impactor observation opportunities by spacecraft, these are the collected notes:

- A discussion took place on the need to have ways to activate the community of amateur observers whenever there is a similar case as the ones occurring in 2022.
- Low-effort interfaces to Earth observing satellite operators should be established to allow detections from space.
- Provision of information at different quality levels has proven of use in the case of GLM (level 2 data was initially used, but availability of level 0 has allowed

[28] https://www.projectpluto.com/sat_id.htm

clear improvements in the process).

For session #4 on fireball networks and other sensing capabilities, these were the main items discussed:

- Currently, infrasound data from the world-wide sensor network of the Preparatory Commission for the CTBTO is regularly used to check for the deposited energy of very bright fireballs. It was noted that national infrasound networks should be activated to participate in this activity too. A dedicated workshop should be planned for this.
- It is suggested to improve communications between the asteroid detection community and the fireball networks and infrasound detection networks.
- Setting up an alert system to registered phone numbers of fireball network operators would be of great use.
- Training of the end users of imminent impactor information by the warning system operators would be useful to help interpreting the provided data.

Finally, the conclusion session treated the following items:

- The current warning systems are providing the information needed to efficiently follow these objects up.
- A better communication shall be established between the warning community and the fireball networks and community of physical properties observation.
- A question is made on whether the community is prepared nowadays to face a Chelyabinsk case with favourable observing conditions.
- Some possibilities are proposed to respond to that question: having dedicated telescopes for physical observations or having agreements for contingency observations / targets of opportunity (ToO) in specific telescopes.
- Official response by Agencies and IAWN on immediate impactors with some larger warning times than just a few hours should be clearly established and exercised.
- There might be the need to have a very fast response procedure at IAWN to activate the civil protection authorities in these cases.
- For objects smaller than 10 m, information on the impact region could be released without problem.
- A distribution list of impact information end users should be established to facilitate the direct connection to satellite operators, fireball network operators, etc.

CONCLUSIONS

Following main conclusions about imminent impactors can be extracted from the above discussions:

- The amount of information provided by the current warning systems is deemed appropriate for the purposes of following up and tracking imminent impactors.
- Efforts should be redoubled to avoid that relevant objects are lost, whenever the observation conditions allow for that.
- Having messages sent to immediate notification / warning applications on mobile phones, as Telegram, should be implemented.
- Standardisation and automated commanding of telescopes should be extended as much as possible in the follow-up and characterisation processes.

- Having pre-established availability of observation time in telescopes able to observe physical properties should be pursued.
- Low effort interfaces to Earth observing satellite operators should be established to allow detections from space whenever possible.
- It is suggested to improve communications between the asteroid detection community and the fireball networks and infrasound detection networks.
- Setting up an alert system to registered phone numbers of fireball network operators should be implemented.
- Training of the end users of imminent impactor information by the warning system operators should be established.
- IAWN should have a specific procedure to inform the relevant stakeholders in case of an imminent impactor compliant with the information rules.

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We are very grateful to all the speakers at the workshop for having provided their talk and presentation to the rest of the community. Furthermore, we would also like to thank all the workshop participants for the fruitful discussions.
A very similar summary was also presented at the 2nd ESA NEO and Debris Detection Conference (2023)[29].

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[29] https://conference.sdo.esoc.esa.int/