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Using Information From Rendezvous Missions for Best-Case Appraisals of Impact Damage To Planet Earth Caused by Natural Objects

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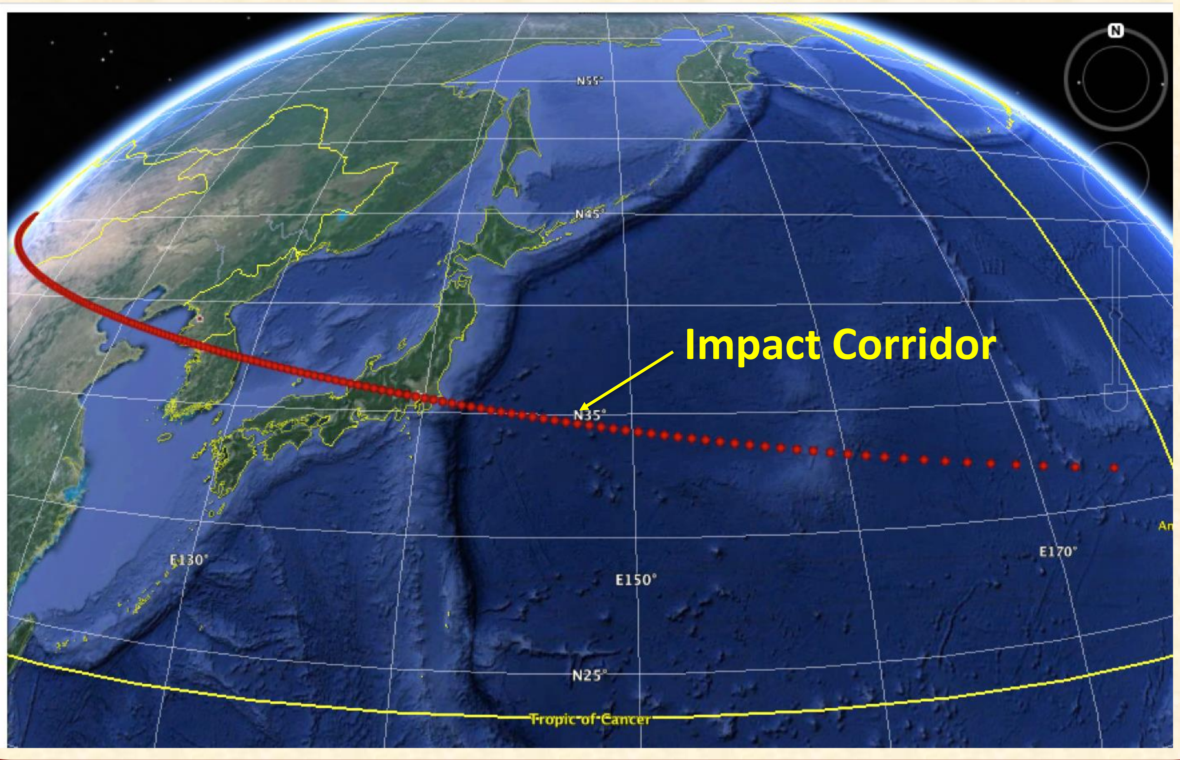
OBJECTIVE & APPROACH

OBJECTIVE:
Specify uncertainty reductions in Probabilistic Asteroid Impact Risk (PAIR) assessments enabled by data from rendezvous missions: Why, How, and What value is added to information to be provided to decision makers?

APPROACH:
Discuss PAIR Assessments of the Hypothetical Asteroid 2017 PDC based on initial observation, and why lack of data leads to uncertainty in the results.

Describe how data from a rendezvous mission can be used to pin-point the asteroid's impact location, improve quantification of devastation levels and how the resulting information would be better suited for officials empowered to take action to mitigate threat from the Hypothetical asteroid 2017 PDC.

IMPACT CORRIDOR AS OF MAY 15, 2017

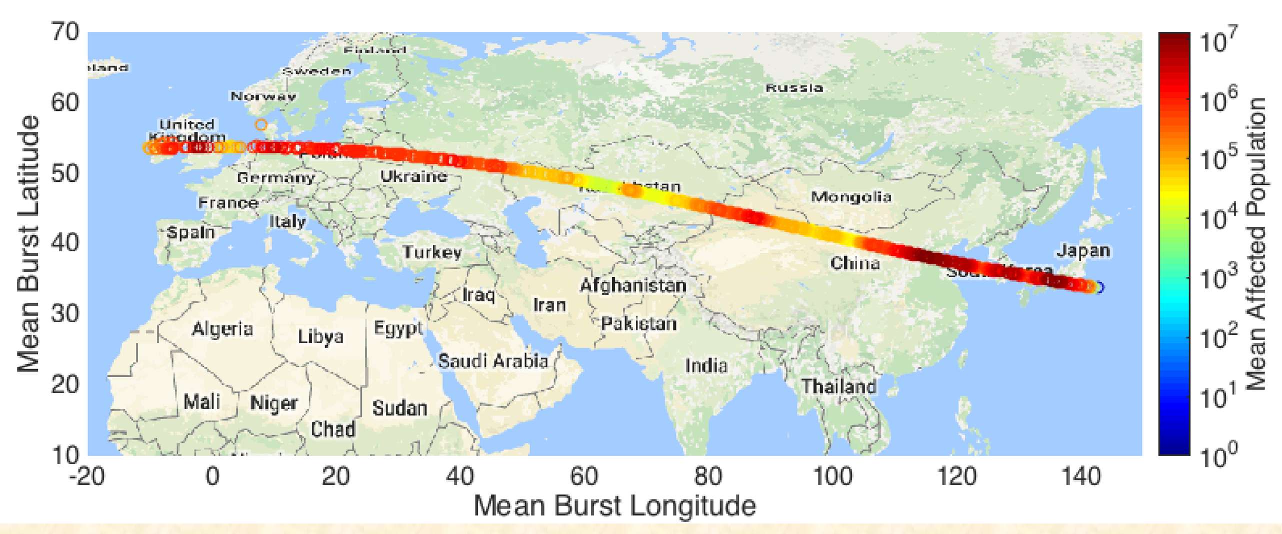


2017 PDC INITIAL OBSERVATION

- Probable impact Corridor Spans the Earth from the Atlantic United Kingdom, Europe, Asia, Korea, Japan and far across the Pacific Ocean.
- Probability of impact is 1 in 100 as of May 15, 2017.
- Absolute Magnitude: 21.9 +/-0.4, corresponding to a size of 160 to 290 m.
- NASA JPL CNEOS provided ATAP entry speed and angles at 100 km altitude along the entire impact corridor. Speed varies from 17.58 to 16.92 km/s. Max entry angle at mid corridor – 47.7^{0}

PAIR RESULTS – Based on MAY 15 , 2017 OBSERVATION

MEAN BLAST DAMAGE TO LAND



MEAN BLAST DAMAGE TO PACIFIC OCEAN

PLOT TO COME FROM DONOVAN/LORIEN

PAIR ASSESSMENT – INITIAL OBSERVATION

- Risk assessment based on same PAIR approach as used for recent Science Definition Study [1] including Asteroid Generated Tsunami model for ocean impacts and Monte Carlo sampling of characteristics from ensemble (Stony, and Carbonaceous).
- Plot shows "Affected Population" versus distance along impact corridor

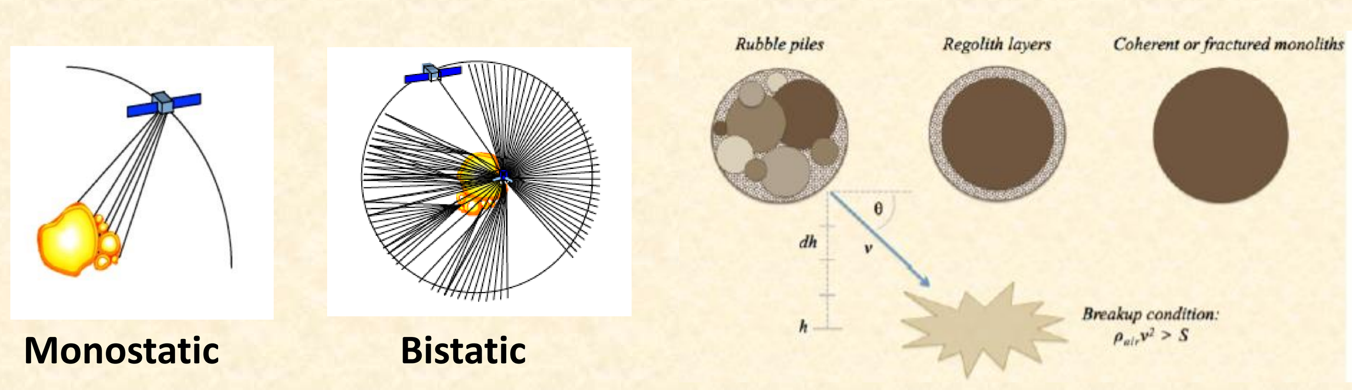
Overpressure Range	Affected Population, %	Expected Damage
68 - 136 mbar 1 - 2 psi	10	Window breakage
136 - 272 mbar 2 - 4 psi	30	Partial collapse of roofs/walls
272 – 680 mbar 4 – 10 psi	60	Partial building destruction
680+ mbar 10+ psi	100	Total building destruction and fatalities

COMMENTS ON INITIAL PAIR ASSESSMENT

- Corridor is very long and will stay that way for years even with ground observations. Values for Affected Population vary widely, 10^3 to 10^7 on land, depending on location and about 10^X for tsunami , depending on mass and other characteristics of 2017 PDC.
- Results for low values of Affected Population suggest that areas exist where "Taking the Hit" might be a possibility for consideration by decision makers e.g. Gobi desert or in the Pacific, far from shore.
- The data with high values of Affected Population suggests that if the strike occurs there, clearly, mitigation action is required.
- The plot has high uncertainty, owing to lack of precision about the 2017 PDC's orbit relating to the strike location, and its physical properties , especially mass, relating to the level of Affected Population.

HOW A RENDEZVOUS MISSION MINIMIZES UNCERTAINTY AND ADDS VALUE TO INFORMATION

- Optical Navigation, combined with ground observations, dramatically improves definition of the asteroid's orbit and predictions of the strike location, probably to less than 100 km for asteroid 2017 PDC.
- In-situ measurements provide detailed information about the asteroids shape, size, mass, spin rate, spin orientation, regolith, sub/interior structure and distribution of the constituent fragments (both location and inhomogeneity).
- The orbit of rendezvous spacecraft provides the effective mass of the asteroid while radar mapping provides detail of mass distribution. The spacecraft also acts as a "shepherd" over long periods, enabling precise definition of the 2012 PDC's orbit.
- Regolith and sub surface definition to tens of meters comes from monostatic radar while definition of the deep interior structure comes from bistatic tomography [2]
- Knowledge from the rendezvous mission provides set-up information for a new ATAP model [3] that can treat entry and breakup of rubble pile and monolithic asteroids that could be representative of 2017 PDC, a part of future sensitivity study.



- Monostatic Bistatic

HOW BEST TO MINIMIZE UNCERTAINTY?

- The answer is to obtain comprehensive data about 2017 PDC with priority on that which best minimizes overall uncertainty in the Risk Assessment.
- The data need to be available in timely manner, so that Risk Assessments can be updated, and information can be provided to decision makers empowered to implement mitigation, or "Take the Hit"
- The BEST way to obtain data about the asteroid is by in-situ observations enabled by a rendezvous mission, complimented with that from an intense, coordinated ground observation campaign.

Bottom Line

- ATAP's Probabilistic Asteroid Impact Risk (PAIR) assessment capability can provide information (WHERE and HOW DEVASTATING STRIKES CAN BE] to decision makers for their deliberations regarding mitigation actions.
- As exemplified by the study of the hypothetical threat from 2017 PDC, it is clear that a rendezvous mission, in combination with ground observations enables the best-case risk assessments.
- Data from a rendezvous mission enables the strike location to be pin-pointed 100 km of less along the very long impact corridor initially available - via the improved orbit.
- In-situ characterization enables refinement of the levels of affected population, helping decision makers decide if the looming threat requires deflection, or not. .

REFERENCES

[1] Mathias, D. L., Wheeler, L., Dotson, J. Aftosmis, M. and Tarano. A. , "Ensemble Risk Assessment in Support of the 2016 NEO Science Definition Team", 5th AA Planetary Defense Conference 2017, Tokyo, Japan

[2] Heriqe, A. et.al, "A Direct Observation of an Asteroid Structure from Deep Interior to Regolith: Why and How? 4th IAA Planetary Defense Conference 13-17 April, Frascati, Rome Italy

[3] Wheeler, L. F. and Mathias, D. L., 2017 "Modeling the atmospheric breakup of varied asteroid structures: inference for the Chelyabinsk meteor and risk assessment application: IAA Planetary Defense Conference, 2017 Tokyo, Japan