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- ☐ **Key International and Political Developments**
- ☐ **Advancements and Progress in NEO Discovery**
- ☐ **NEO Characterization Results**
- ☐ **Deflection and Disruption Models & Testing**
- ☒ **Mission & Campaign Designs**
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- ☐ **Disaster Response**
- ☐ **Decision to Act**
- ☐ **Public Education & Communication**

HOW WE BEAT 2019 PDC TO NYC BY 2 YEARS, WITHIN 2 YEARS, 2 YEARS AGO

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ABSTRACT

For the Planetary Defense Conference *Exercise* 2019, we set out to find ways to obtain the earliest possible characterization of the incoming (*fictitious!*) asteroid, 2019 PDC. After a partially successful deflection, a small fragment was still bound for impact. The location was only known two weeks before impact – the time left for the evacuation of the larger New York City metropolitan region. With experience in Near-

Earth Object (NEO) exploration mission design, solar sail and solar-electric propulsion (SEP) technology for small spacecraft, agile responsive design and integration, and from previous exercises, the importance of earlier information on impact location and energy was obvious. NEO in-situ exploration can provide invaluable information not just for deflection actions but also for planetary science and resource utilization. This is only possible with space missions closely approaching the asteroid. Expecting a solar sail mission flying in the 2020s could be re-directed, a unique feature of solar sailing, we searched for multiple rendezvous missions at initial sail technology characteristic accelerations of ≤ 0.10 mm/s^2. We found numerous options of up to three NEO encounters in the launch window 2019-2027 but none could divert to 2019 PDC in time. In addition, we explored very steerable and throttleable low-thrust solar-electric propulsion (SEP) rendezvous to a particular group of NEOs, the Taurid swarm which was expected to become observable in the summer of 2019, with a possible impact threat in the early 2030s. An acceleration of 0.23 mm/s^2 would suffice for a rendezvous in $\approx$2000 days. Shorter transfers are available at higher acceleration. Finally, we found two low-thrust options to 2019 PDC, one sail and one SEP, both arriving about 2 years before impact at the fragment, requiring 0.3 mm/s^2 acceleration – about the performance limit we estimate for “now-term” technology. They require launch within less than 2 years of discovery of 2019 PDC, which we consider feasible provided that the basic technology has been flown. This is the case for SEP but not yet for solar sails of which only a few demonstrators were flown. SEP has become a mainstream propulsion method. Soon, the majority of all spacecraft ever launched will be small SEP spacecraft. DLR GOSSAMER solar sails use a strategy for controlled deployment of large membranes based on a combination of zig-zag folding and coiling of triangular sail segments spanned between crossed booms, all unfolded by dedicated deployment units. To reduce the complexity of this system for fast-tracked initial solar sail flights an adaptation of that deployment strategy was developed that allows deployment actuation from a central bus. The mass of such a sailcraft will be slightly increased but its performance is still reasonable for first solar sail missions. This design was breadboarded to demonstrate feasibility of the deployment strategy and its performance analyzed. On this background we developed two preliminary spacecraft designs by taking SEP off-the-shelf and getting solar sails into space soonest. We present how we beat 2019 PDC to NYC by >2 years, within <2 years, 2 years ago – and didn't tell anyone.

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Comments: *oral presentation preferred, poster (or equivalent) welcome*

(Alternative session, Time slot, Oral or Poster, Etc…)