Searching for Near Earth Objects: an IR Telescope in a Venus-like Orbit. Roger Linfield[1], Jeffrey VanCleve[2], Harold J. Reitsema[3], and Robert Arentz[4], [1]Ball Aerospace & Technologies Corp. (Ball Aerospace & Technologies Corp., Mail Code RA-4, P.O. Box 1062, Boulder, CO 80306; rlinfiel@ball.com), [2]Ball Aerospace & Technologies Corp. (Ball Aerospace & Technologies Corp., Mail Code FT-4, P.O. Box 1062, Boulder, CO 80306; jvanclev@ball.com), [3]Ball Aerospace & Technologies Corp. (Ball Aerospace & Technologies Corp., Mail Code RA-2, P.O. Box 1062, Boulder, CO 80306; hreitsema@ball.com), [4]Ball Aerospace & Technologies Corp. (Ball Aerospace & Technologies Corp., Mail Code RA-2, P.O. Box 1062, Boulder, CO 80306; rarentz@ball.com),

Summary: We present a design for a mission to discover 90% of all diameter D>140 m Near Earth Objects (NEOs) within ≈7 years. A single spacecraft in a Venus-like orbit will contain an actively cooled IR telescope, observing in the 6 – 11 micron band.

Details: Our spacecraft orbit, in the ecliptic plane and with perihelion and aphelion of 0.60 and 0.80 A.U., is achieved by means of a passive, gravity-assisted Venus flyby, with no propulsive maneuvers after leaving Earth orbit.

The IR telescope has a 50 cm diameter primary mirror: our four mirror off-axis design gives an 11 square degree field of view. Thermal models predict that our closed-cycle Stirling cooling system (a flight-proven, long-life Ball Aerospace design) can maintain the telescope optics at 65 K throughout the orbit, with the 25 megapixel detector cooled to 40 K.

Using our engineering design for the spacecraft, telescope, and detector, we have developed a system performance model to determine the completeness level of a survey. This model uses the current best estimates for the distribution of NEO sizes, orbits, and albedos.

Our simulations show that we can achieve a completeness for D>140 m NEOs of 88% in seven years or 90% in eight years.

IR observations outperform visible observations for NEO detection, for several reasons. First, most of the energy from NEOs is in the IR band (15 – 20 times more for the low albedo objects). Second, since there are more photons per joule in the IR, shot noise averaging and background subtraction gives a higher SNR. Third, the fact that NEOs are viewed in emission in the IR, vs. reflection in the visible, makes the phase function much more favorable in the IR. IR observations have an additional advantage because IR emissivities are more uniform than visible albedos, leading to better size estimates for NEOs that are discovered.

Larger telescopes do not significantly improve survey completeness, due to a phasing problem. The NEOs with the longest orbital periods (4 – 8 years) spend almost all their time far from the sun, where they are quite faint in both IR and visible bands when observed from Earth or Venus orbit. These NEOs only pass perihelion once during an observing program of ~7 years. If this passage happens when the spacecraft is on the other side of the sun, the NEO will be outside the telescope field of regard and not accessible. Attaining substantially better completeness requires a second telescope in a different orbital location, either in the same orbit but ~180 degrees away (an anti-correlated location), or else on the Earth (an uncorrelated location).

If we add a visible telescope on Earth to our observing network, the seven year completeness rises to 93% for a Pan-STARRS1 (1.8 m diameter) ground telescope or 95% for a dedicated LSST.

Our current design (with a 50 cm IR telescope) will cost more than a Discovery mission. Our system performance model allows us to quantify the often non-intuitive impacts of various design changes that reduce the cost. We can modify our design to fit the Discovery cost cap, while minimizing the performance degradation. Within the Discovery budget, we anticipate being able to achieve ≈90% completeness in seven years with a space IR plus ground visible combination.

Asteroid Science: The scientific element of this mission studies the collisional history and future of asteroids. There are 3 specific topics in this theme: the Yarkovsky Effect, the YORP effect, and recent collision-generated asteroid families. The *Yarkovsky Effect* ("Yark") is the force on a small body due to asymmetric re-radiation of absorbed sunlight on the warmer "afternoon" side of a spinning asteroid. Combined thermal IR and visible observations, and radar or optically-measured Yark perturbations, can then be interpreted to calculate mass, density, and inferred porosity. The *YORP Effect* is the angular momentum complement to Yark. Yark and YORP are coupled, in that Yark depends on the spin state of the body, which in turn depends on YORP. *Asteroid families* are the result of collisions in the Main Belt. Their detailed structure in orbital element space is a fingerprint of the velocity field produced by the initial collision, and also reflects past orbital evolution by Yark/YORP. Understanding the formation and migration of asteroids into potentially hazardous (or useful) orbits in the Near-Earth region requires relating all three topics, with a representative sample of asteroids from each of the dynamical reservoirs of NEOs.