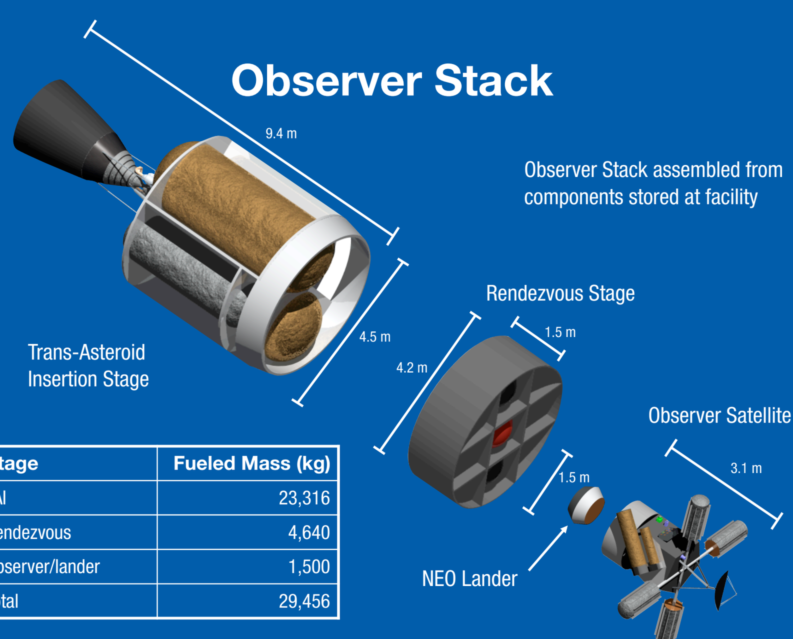
National Aeronautics and Space Administration

Towards Designing an Integrated Architecture for NEO Characterization, Mitigation, Scientific Evaluation, and Resource Utilization

Characterization Track

If an NEO is detected to be a threat to the Earth, beyond a certain threshold, then the central facility will assemble an observer to be launched as soon as possible.

Observer Stack

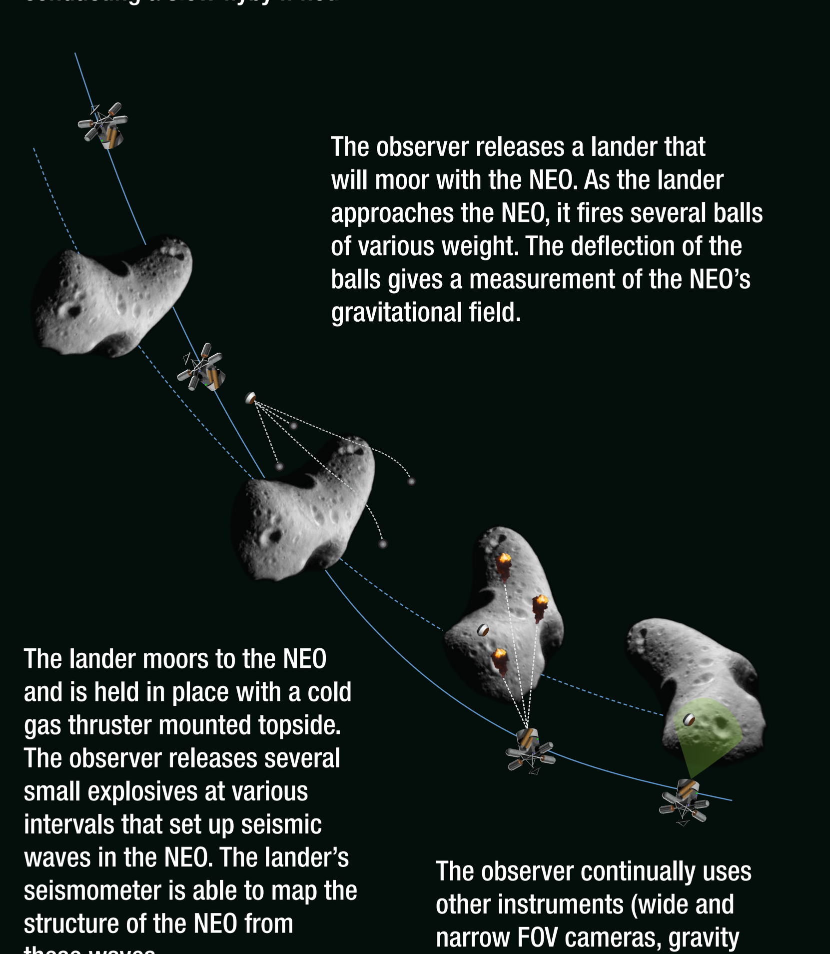


Stage	Fueled Mass (kg)
TAI	23,316
Rendezvous	4,640
Observer/lander	1,500
Total	29,456

Alternatively, if the NEO scientific community identifies an NEO of particular scientific interest, then the same observer stack is assembled and launched at an optimum point to achieve a full scientific analysis.

The observer stack can be launched on a number of existing and proposed launch vehicles. Some non-U.S. vehicles may have the needed performance as well.

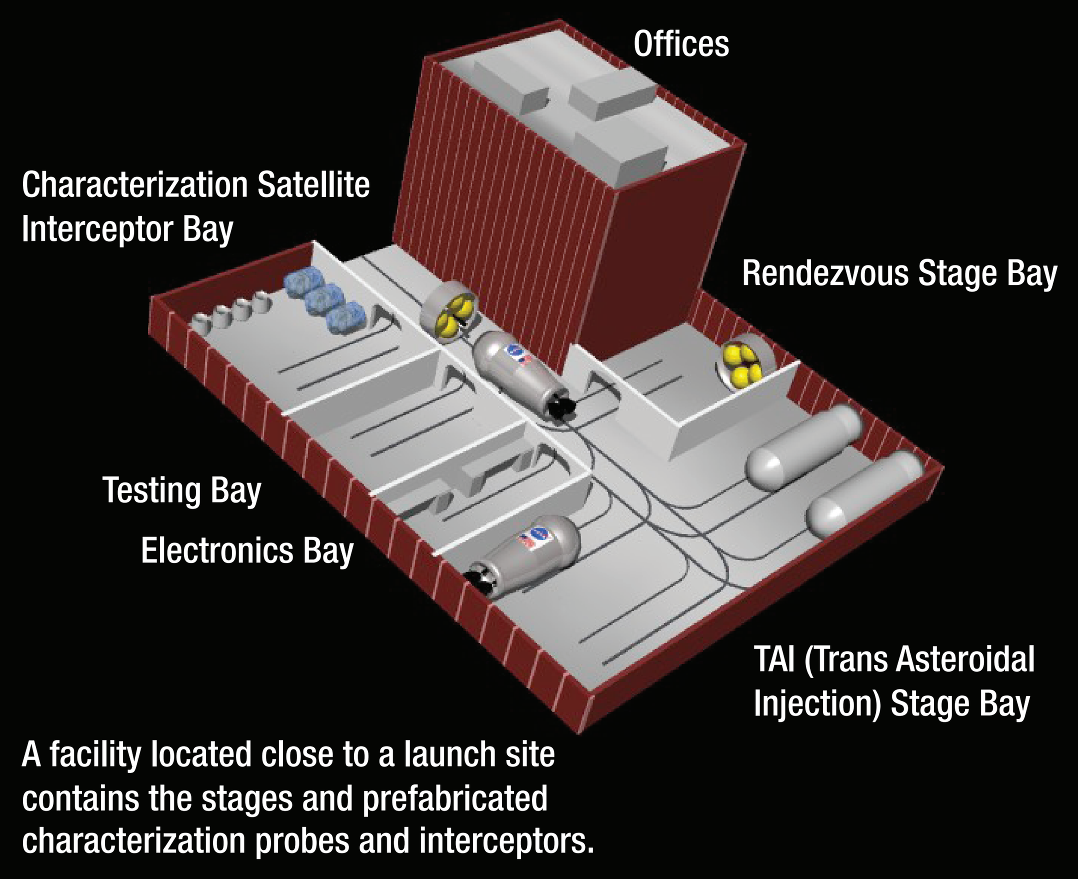
As the observer approaches the NEO, it exhausts the propellant in the rendezvous stage, matching orbit with the NEO if possible, conducting a slow flyby if not.



The observer releases a lander that will moor with the NEO. As the lander approaches the NEO, it fires several balls of various weight. The deflection of the balls gives a measurement of the NEO's gravitational field.

The lander moors to the NEO and is held in place with a cold gas thruster mounted topside. The observer releases several small explosives at various intervals that set up seismic waves in the NEO. The lander's seismometer is able to map the structure of the NEO from these waves.

The observer continually uses other instruments (wide and narrow FOV cameras, gravity sensors, spectrograph, penetrating radar, and laser ranger) to extract as much data as possible from the NEO.

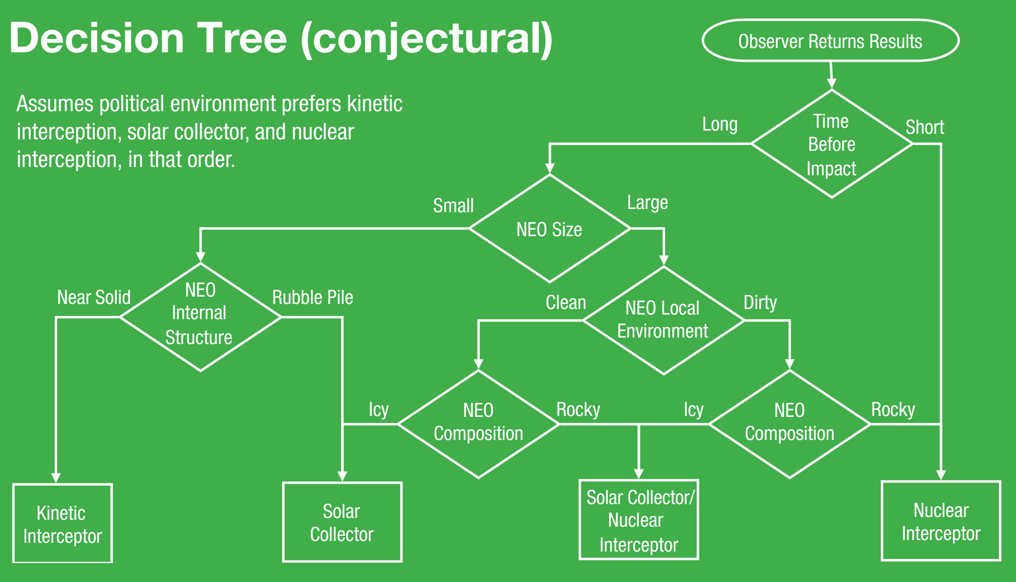


A facility located close to a launch site contains the stages and prefabricated characterization probes and interceptors.

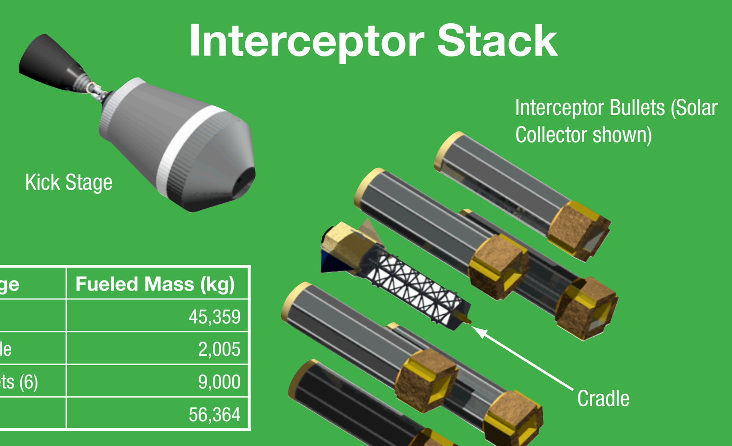
Deflection Track

If an NEO is found to pose a significant threat, then a mitigation system will be launched. The mitigation system used can be of a variety of options. Three options are shown here, but others could easily be included.

Decision Tree (conjectural)



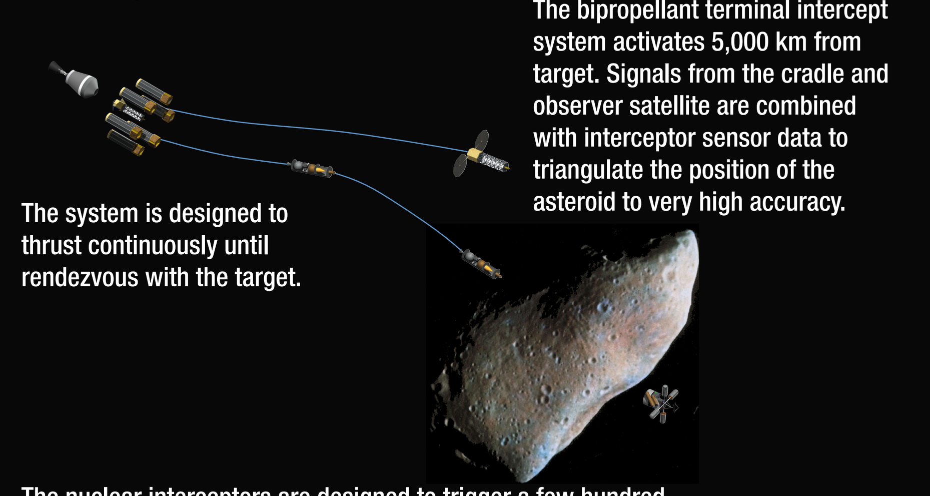
Interceptor Stack



Stage	Fueled Mass (kg)
Kick	45,359
Cradle	2,005
Bullets (6)	9,000
Total	56,364

After selecting the mitigation system, the magnitude of the threat will determine the method of launch. The Ares V system is capable of launching up to six mitigation systems simultaneously. A single mitigation system can be launched on an Ares I, Atlas V, Athena, or a Delta IV Heavy.

Each deflection system is released from the cradle. Each system independently flies to the target. The release point is designed to allow impacts at 1-hr intervals.

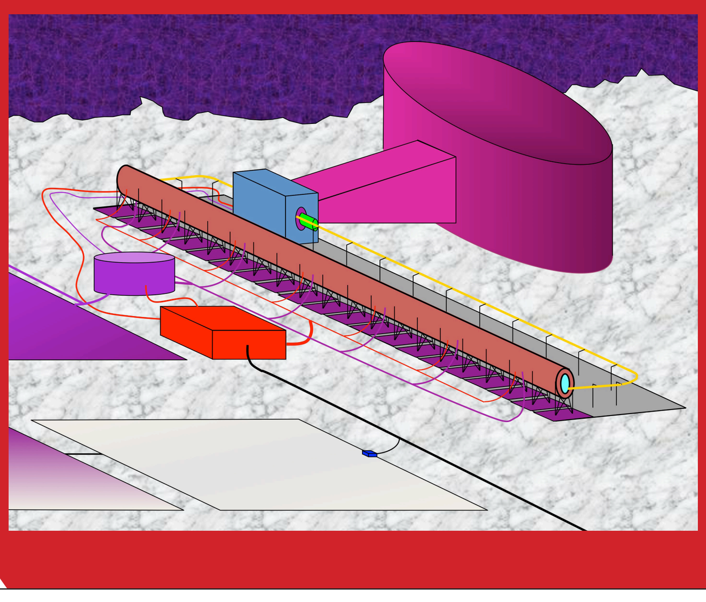


The bipropellant terminal intercept system activates 5,000 km from target. Signals from the cradle and observer satellite are combined with interceptor sensor data to triangulate the position of the asteroid to very high accuracy.

The system is designed to thrust continuously until rendezvous with the target.

The nuclear interceptors are designed to trigger a few hundred meters from target. The kinetic impactors make physical contact at the highest possible closure speed.

Exploration Track



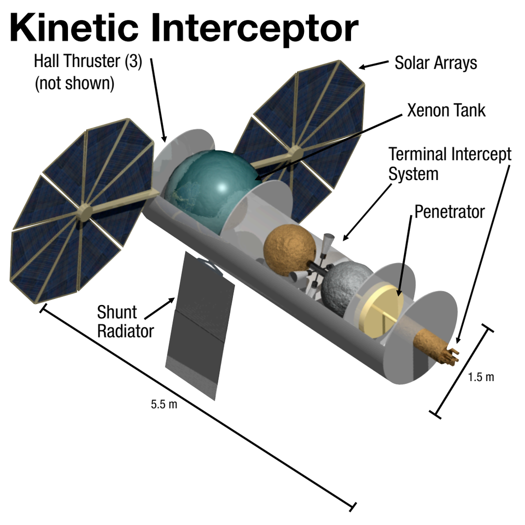
This system holds the promise of enabling NEO crewed exploration as well as in situ resource utilization for further space exploration. This track will be investigated at a later date.

ANNOUNCEMENT

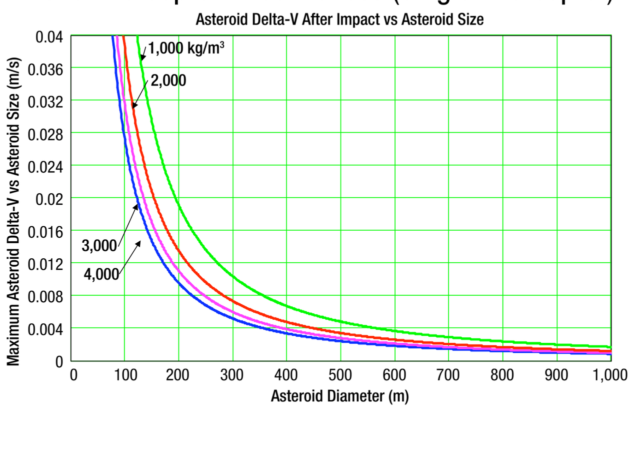
NASA MSFC is investigating hosting an interactive workshop on the issue of orbital debris. This workshop would entail collaboration between NASA design engineers and anyone with a concept for reducing the population or mitigating the debris that exists in low-Earth orbit. Participants would provide their own resources to produce a design that would be linked with MSFC's launch vehicle and spacecraft design tools to produce an integrated design concept. A workshop is anticipated in the fall 2009 timeframe for all participants to refine their concepts and comment on the other proposals.

For more information or to express your interest in this workshop, please e-mail: <robert.b.adams@nasa.gov>.

Kinetic Interceptor

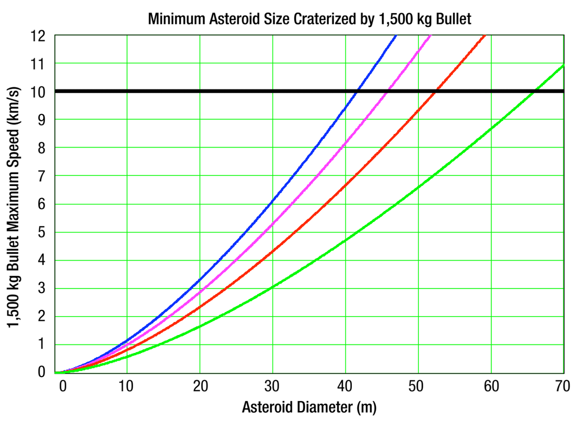


Kinetic Interceptor Effectiveness (Single Interceptor)

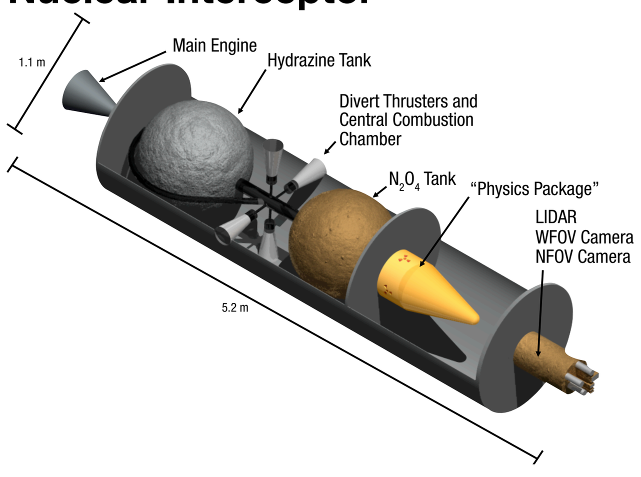


Physics of Kinetic Interception

- Made estimate of maximum impact velocity without fracture
- Assumed inelastic collision of kinetic interceptor with NEO
- Momentum from potential ejecta not included

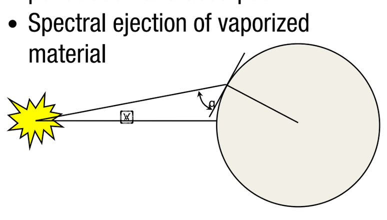


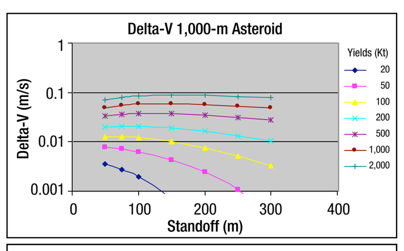
Nuclear Interceptor

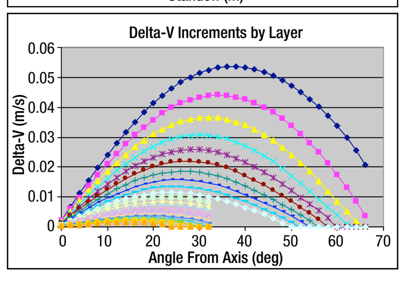


Physics of Nuclear Deflection

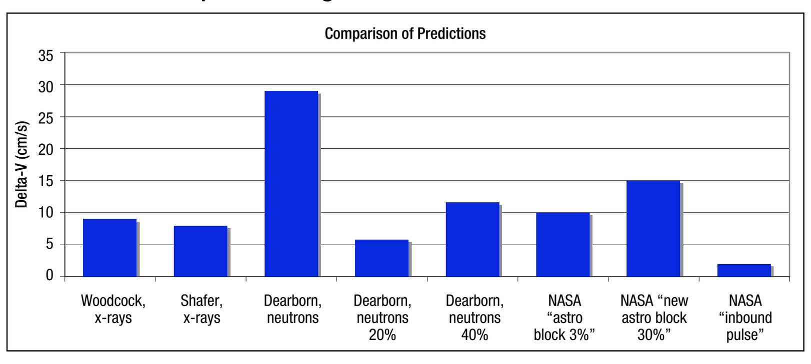
- Explosion at optimum standoff distance from NEO
- Explosion to cover maximum surface that can be ablated
- Only x-ray interaction with NEO considered here
- Monte Carlo model of x-ray penetration and absorption
- Spectral ejection of vaporized material

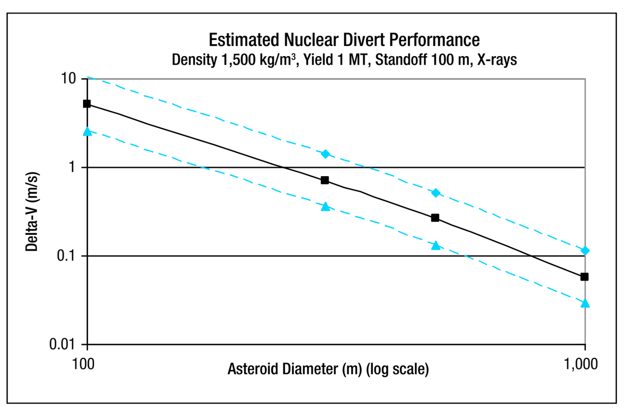




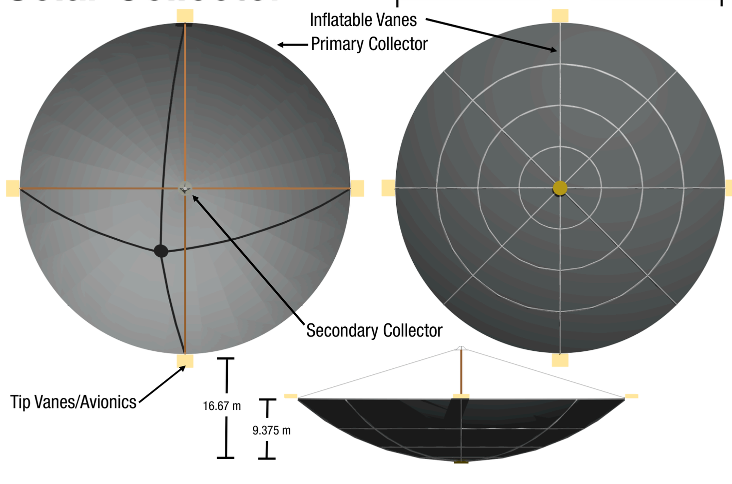


Prediction Comparison Against Other Models in Literature

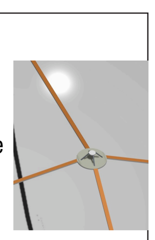




Solar Collector



Design

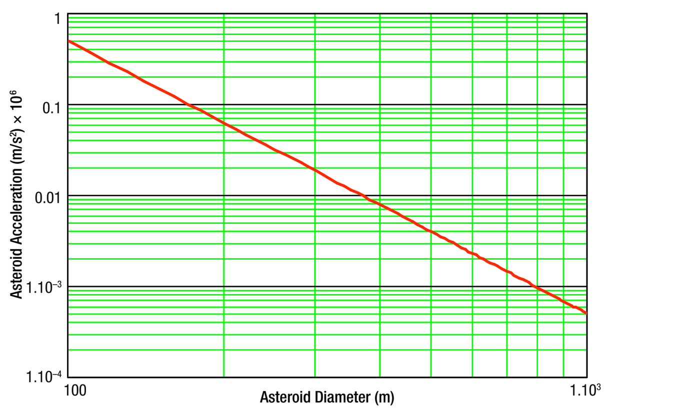


- Primary Collector
  - Made of solar sail materials
  - Folded "parachute-like" to fit in allowable bullet volume
  - Inflated using vanes along major seams, nitrogen gas cures thin film laminate vanes after inflation
- Secondary Collector
  - Thin film of gold layered on beryllium plating
  - Niobium heat pipes with potassium working fluid mounted on back side of beryllium plating to radiate away heat
  - 0.5-m Sun shield mounted 0.5 m away from secondary
- Tip Vanes
  - Solar arrays double as tip vanes for attitude control
  - Redundant communications and avionics systems at all four tip vanes

Physics of Solar Collector

- Primary collector always faces Sun
- Estimate of performance assumes 1 AU distance from Sun
- Secondary collector located at focus
- Beam from secondary directed on NEO
- Beam penetration into crust vaporizing material
- Ejecta transmits momentum to NEO
- Secondary collector sized to
  - Handle aberration from nonuniformities in parabolic primary
  - Nonpoint source for Sun
  - Secondary not perpendicular to focus plane from primary
- Collector efficiency estimated at 50% incident on primary

Solar Collector Effectiveness (Single Collector)



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