Considerations for Planetary Defense

William Ailor, Ph.D.
The Aerospace Corporation

August 10, 2010
Detect and verify NEO threat as far away from Earth as possible
Move threatening NEOs to non-threatening orbits
Requirements:
• Perform comprehensive search and survey for potential threats
• Precise tracking & orbit predictions to assure threat is real as far ahead of potential impact as possible (minimize false alarms)
• Means to apply force to approaching NEO sufficient to reduce probability of impact below acceptable limit
• Verification that mitigation attempt worked
Why a human?

- Risk reduction—need to know as much as possible about nature of NEOs and how a threatening object might respond to a mitigation attempt
  - Need to understand small forces that affect tracking (e.g., Yarkovsky); understand how mitigation attempt might change those forces
  - Need to understand how activities might affect attached sensors and hardware (e.g., Lunar dust)
  - Need to reduce uncertainty for slow push, impulsive mitigation techniques
  - Carefully designed and executed experiments can provide answers
  - Need to understand NEO physical properties including local properties, global properties, and variations among NEO populations

- Human mission expands experiment options, mission success
  - Multiple experiments using multiple protocols at multiple locations during same mission

- Human observation and involvement provides insights on the unexpected
  - Insights derived addressing problems increase understanding (e.g., dust on lenses, dust on visors, attachment problems)
  - Data from multiple sensors could improve knowledge of structure, composition, response to mitigation attempt (e.g., seismic info from explosion or impact test)
Accurate tracking essential for assessing threat, verifying mitigation success
- Impact predictions affected by thermal re-radiation effects (Yarkovsky)
- Yarkovsky effects depend on NEO characteristics: bulk density, size, thermal conductivity, rotation rate, rotation pole direction

Options for improving tracking
- Landed transponder or reflector
  - Requires landing/attachment system
  - Solar power and communications possibly limited by asteroid rotation
  - NEO environment (dust) might affect performance
- Information from spacecraft orbiting or station keeping nearby
  - Images and data also help determine NEO shape, mass, rotation rate, bulk density, existence of companion “moon”
  - Could be essential for verifying success of mitigation mission

Options for improved orbit prediction
- Information on object’s size, shape, rotation rate, rotation pole direction, mass
- Thermal conductivity
Move an Object: Slow Push Techniques

- Attach rocket motor, mass driver, other device to the surface to “push” NEO
- Use gravitational attraction between nearby spacecraft to “pull” NEO to new orbit (Gravity Tractor)
- Shine laser or solar energy on surface to impart small force
- Apply force over period of weeks to months
- Requires
  - Info on mass, shape, dynamics
  - Interacting with surface or operating in close proximity for long periods
  - Confidence that attachment; precise orbit/station-keeping control of Gravity Tractor; laser or solar interaction will work as planned
  - Accurate tracking to know when mission successful; possibly target subsequent attempts
Move and Object: Impulsive Techniques

• Impact NEO with projectile at very high relative velocity (Kinetic Impact; e.g., Deep Impact mission)

• Detonate explosive device above, on, or below the surface of the NEO

• Requires
  – NEO mass
  – NEO type (rubble pile, solid body)
  – NEO composition (iron, rock, etc.) & properties
  – Accurate tracking post event to verify success, target subsequent attempts
Gather data, test techniques for improving threat prediction, mitigation verification

- Test & characterize techniques for attaching transponders, other devices to NEO
- Test technology required for long-term station-keeping and orbiting a NEO
- Collect detailed information on shape, size, mass, bulk density, thermal properties, rotation
- Leave capability to verify effectiveness of mitigation techniques (e.g., observer spacecraft)
• Measure mass properties, begin database of physical characteristics to narrow uncertainty (homogeneity, etc.)
• Test and characterize mining concepts
• Observe effects of laser impingement, focused solar on NEO surface
• Assess effect of human activities on NEO environment (e.g., will dust coat tracking reflectors, affect transponder performance?)
• Develop model of NEO’s gravitational field for development and testing of station-keeping concepts
• Return samples of NEO and compare bulk density of samples with bulk density of NEO to estimate porosity (useful for mitigation)

• Design spacecraft to maintain close station with NEO (verify thrusters don’t impinge, active control system and sensors function as required)

• Observe (with remote spacecraft) kinetic impact and measure effect

• Coordinate in-depth human exploration with broad robotic surveys