NEO SKGs in view of ARM

Andy Rivkin, who hasn't asked the other members of the SAT about this

Some setup

- Until earlier this year, the expectation has been that we'd send astronauts to an NEO in deep space
- SBAG stood up a team at NASA's request to look at "Strategic Knowledge Gaps" (next slide)
- The Asteroid Retrieval (Redirection?) Mission (ARM) proposes moving a 8-m NEO to high lunar orbit to serve as a new target for astronauts
- At this writing, other details are TBD
  - We may know more when I'm actually speaking
  - *Updated, Tuesday night: not really*
- Now we need to think about SKGs for the robotic retrieval/redirection phase in addition to the actual human visit

In context:
8-m sized objects

"Strategic Knowledge Gaps"

- "The gap between what the organization needs to know and what it knows now"
- Taking a human visit to an NEO as a given*, what don't we know how to do, and how do we learn to do it?
- Ultimately, generate list of measurements, allowing design of precursor missions

Figure 15.3

Zack, in *The Strategic Management of Intellectual Capital and Organizational Knowledge*, Choo & Bontis eds. (2002)

*Just for the purposes of this slide

…for instance:

- Goal: Ensure Kryptonian race survives planetary destruction
- Path: Evacuate inhabitant (s) to intact planets
- Example SKGs
  - Fraction of planets within reach that are habitable
  - Effects of non-K/M star on Kryptonian life
  - Likely reactions of less-advanced civilizations to “first contact”

Morrison and Quitely, 2008

SB SKG Themes and Categories

SB SKGs can be organized into several themes, which can be further divided into categories:

I. **Human mission target identification (NEOs).** The identification of multiple targets for human exploration is fundamental.

II. **Understand how to work on or interact with the SB surface.** Human presence may disturb the environment in non-intuitive ways. We need to understand how best to perform sample acquisition and handling, instrument placement, and proximity operations.

III. **Understand the SB environment and its potential risk/benefit to crew, systems, and operational assets.** The small body environment may include dust emitted periodically (for instance via levitation) or episodically (after impact or spin-up events). It may enhance or screen solar radiation. It may be gravitationally metastable.

IV. **Understand the SB resource potential.** ISRU is considered a "game changer" in how humans explore the Solar System by enabling an infrastructure that allows a sustainable human presence in space. The short-stay missions likely to be in the first wave of NEO or Phobos/Deimos visits may test or prepare that infrastructure but are unlikely to take advantage of it.

SBAG SMALL BODIES ASSESSMENT GROUP

Critical Items

Timescale	SKGs: Number and Name
Near	1. I-A Constraints on targets: Reachable targets within architecture and radiation exposure limits 2. I-B NEO orbit distribution
Mid	1. I-C-3: NEO rotation state 2. II-C-2: Geotechnical properties of SB surface 3. II-D-1:Anchoring for tethered activities 4. II-D-2:Non-contact proximity operations development 5. III-A-1: Particle environment, undisturbed 6. III-A-3: Particle environment post-disturbance 7. III-B-1: Local effects post-solar flare 8. III-B-2: Small body surfaces as secondary radiation sources 9. III-D-1: Local structural stability 10. III-D-2: Global structural stability
Long	1. III-A-2: Phobos/Deimos torus characterization

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Long	1. III-A-2: Phobos/Deimos torus characterization

Critical Measurements: Part 1

Measurement	SKGs: Number and Name	Notes
Orbit/Size/Frequency of NEOs in accessible orbits to 30 m size	I-A-1, I-A-2, I-B-1, I-B-2	Survey where possible, modeling as necessary. Size from HQ.
Biological Research	I-A-1, I-A-2, I-B-1, I-B-2	Better defined by bio experts
Propulsion Research	I-A-1, I-A-2	Better defined by propulsion engineers
Shielding Research	I-A-1, I-A-2	Better defined by engineers
Radiation dosimetry in asteroid milieu	I-A-1, I-A-2, III-B-1, III-B-2	Details better defined by bio experts. CRaTER, RAD example instruments
Measure rotation rate of target asteroid to 15 minute precision	I-C-3, III-D-1, III-D-2	After target is selected; combination of Earth-based, spacecraft, in-situ study as necessary.
Measure rotation rates in NEO population for ensemble properties	I-C-3	Combination R&A, spacecraft study
Model sparsely-sampled lightcurves to understand biases	I-C-3	Some data will be available from LSST/Pan-STARRS, but optimized for discovery not lightcurve collection.
Studies of "how quickly-rotating is TOO quickly-rotating" for target.	I-C-3, II-D-2	Details better defined by bio experts (human factors) and engineering experts (operations issues)
Measurement of mass (in-situ radio science)	II-C-2, III-D-1, III-D-2	If multiple system, remote measurements also possible. Sufficient precision to support 5% precision on density.
Measurement of volume/shape model (in-situ imaging/LIDAR)	II-C-2, II-D-1, II-D-2, III-D-1, III-D-2	Radar (if observable), lightcurve observations also applicable. Sufficient precision to support 5% precision on density, understand local gravity to factor of 10.

Critical Measurements: Part 1

Measurement	SKGs: Number and Name	Notes
Orbit/Size/Frequency of NEOs in accessible orbits to ~~30~~ 8 m size	I-A-1, I-A-2, I-B-1, I-B-2	Survey where possible, modeling as necessary. Size from HQ.
~~Biological Research~~	~~I-A-1, I-A-2, I-B-1, I-B-2~~	~~Better defined by bio experts~~
Propulsion Research	I-A-1, I-A-2	Better defined by propulsion engineers
~~Shielding Research~~	~~I-A-1, I-A-2~~	~~Better defined by engineers~~
~~Radiation dosimetry in asteroid milieu~~	~~I-A-1, I-A-2, III-B-1, III-B-2~~	~~Details better defined by bio experts. CRaTER, RAD example instruments~~
~~Measure rotation rate of target asteroid to 15 minute precision~~	~~I-C-3, III-D-1, III-D-2~~	~~After target is selected; combination of Earth-based, spacecraft, in-situ study as necessary.~~
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Measurement of volume/shape model (in-situ imaging/LIDAR)	II-C-2, II-D-1, II-D-2, III-D-1, III-D-2	Radar (if observable), lightcurve observations also applicable. Sufficient precision to support 5% precision on density, understand local gravity to

Critical Measurements: Part 2

Measurement	SKGs: Number and Name	Notes
Calculation/constraint on mass/ density, thermal properties via measurement of YORP (long-term lightcurve/radar observations)	II-C-2, III-D-1, III-D-2	Ground/Earth-based. Obsoleted by in-situ data Not obtainable in all cases.
In-situ measurement of cohesion/ shear strength/etc. (imaging, surface disturbances)	II-C-2, III-D-1, III-D-2	Impactor? Observation of plume impingement?
Near-surface porosity of target	II-D-1	In-situ or ground-based radar.
Engineering research	II-D-2	Including thruster contamination threshold for science
~~**Measurements of dust density at target**~~	~~III-A-1, III-A-3, III-A-2 (at Phobos/Deimos)~~	~~In-situ observations.~~
~~**High phase angle, long-duration imaging at target**~~	~~III-A-1, III-A-3, III-A-2 (at Phobos/Deimos)~~	~~Search for dust/dust levitation. In-situ. Also insights from Rosetta/Hayabusa 2/OSIRIS-REx/ completed mission data~~
~~**In-situ radiation monitoring**~~	~~III-B-1, III-B-2~~	~~Also data mining of XGRS/GRS from NEAR/ Hayabusa?~~
~~**High phase angle, long-duration imaging at target**~~	~~III-A-1, III-A-3~~	~~Search for dust/dust levitation. In-situ.~~

A few thoughts on what's changed

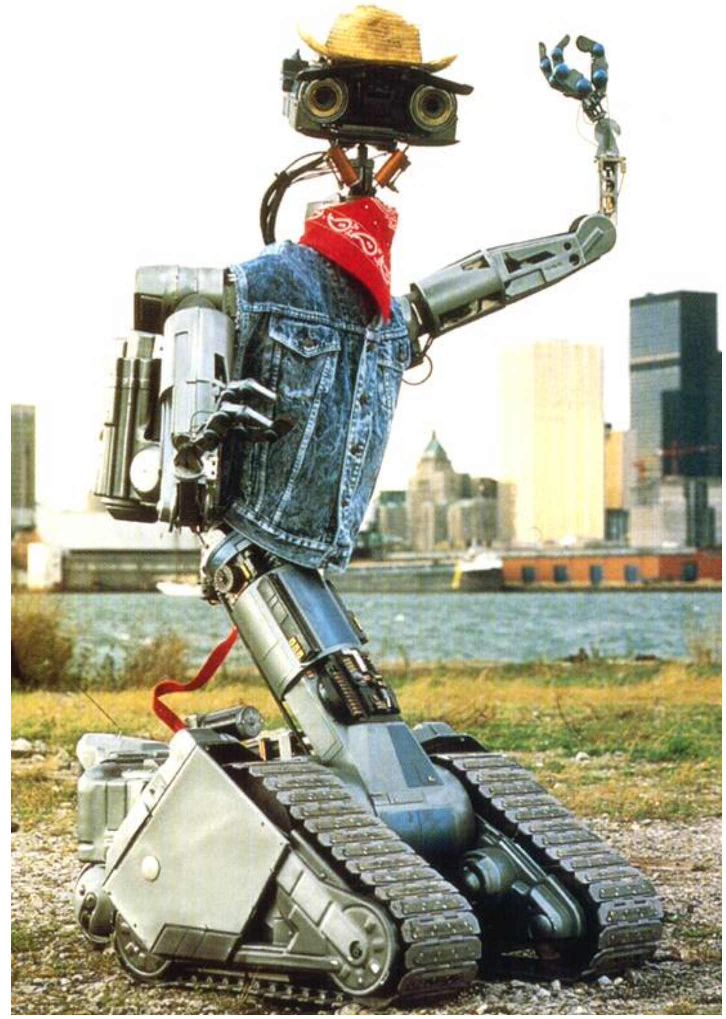
- Survey
- Proximity Operations
- Science output
- ISRU
- Bio/etc. issues

Survey

- Previous concept needs object in particular orbit, bigger than 30 (15?) m.
  - Almost anything in the right orbit would probably have been fine: Odds are it'd be big enough
  - No penalty for larger objects
- New concept needs object not too big or too small
  - Unlikely to find good enough objects in course of ongoing surveys?
  - Doable at all from interior to Earth given target sizes and necessary orbits?
  - Definitely need albedos: factor of ~3 uncertainty in size from
  - Serious constraints relating to getting physical observations

Proximity Operations

- Much of the danger/ uncertainty shifts from human visit to capture:
  - Object to be despun before human visit
  - If a rubble pile, structure may be destroyed during capture
  - Desired infrastructure could be installed during capture?



Ready for the asteroid round-up!

In-Situ Resource Utilization (ISRU)

- Not obvious (to me) how well this will be demonstrable
  - Small mass
  - Odds against target having extractable hydrated minerals
  - Harris suggests 8-m population dominated by lunar ejecta (so no metals either?)

Bio/etc. issues

- Mostly beyond scope of SBAG concern
- Has been noted in many places that this is no longer really a deep space mission

Science output

- Stressed by NASA people this is “not a science mission”
- Not obvious how much (if any) sample returned
- Not obvious how many (if any) Decadal Survey goals met
- Potential for lots of science, not obvious how much will be achievable in capture phase

Summary

- The ARM concept, as currently understood, differs significantly from the previous idea of a human NEO visit
- Some of the previous set of SKGs no longer seem as important, but some relating to the capture/redirection phase become more critical
- A more formal update may be worthwhile once the situation settles