THE HERA MULTIPLE NEAR-EARTH ASTEROID SAMPLE RETURN MISSION: SELECTION OF THE TARGET ASTEROIDS. D. W. G. Sears[1], D. J. Scheeres[2], and R. P. Binzel[3]. [1]Arkansas-Oklahoma Center for Space and Planetary Sciences and Dept. Chemistry and Biochemistry, Univ. Arkansas, Fayetteville, Arkansas 72701 (dsears@uark.edu). [2]Dept. of Aerospace Engineering, Univ. Michigan, Ann Arbor, Michigan 48109. [3]Dept. of Earth, Atmospheric and Planetary Sciences, Massacussetts Inst. Technology, Cambridge, Massachussetts 02139.

Introduction: The spectacular success of the NEAR Shoemaker mission suggests that sample return from near-Earth asteroids is within our technological grasp. At the same time, many major questions posed by the laboratory investigation of meteorites and the astronomical study of asteroids can only be satisfactorily addressed by the return of samples [1]. Returned samples will enable us to understand the rocks in terms of their geological context, and they will provide ground truth for astronomical observations. Returned samples offer the best opportunity to resolve questions that have occupied an entire career [*e.g.* 2].

The Hera Mission: Hera is a proposed Discovery class mission that will visit three near-Earth asteroids, reconnoiter each for at least two months, descend to the most scientifically significant sites to collect samples by a touch-and-go method, and return the samples to Earth [1]. Hera's objective is to collect enough material that every qualified scientist can receive samples, ~1 kg in total (~100 g at three sites on three asteroids).

The Hera mission faces two major challenges, the design of the collector [3] and the selection of asteroids [4]. This paper concerns asteroid selection. Our approach to asteroid selection has been to identify the most dynamically favorable asteroids and then try to obtain the required information on them. The required information is that which affects the engineering and dynamics of the spacecraft, and that which maximizes the scientific value of the mission. As we have discussed elsewhere [4], the information required for design of the close proximity operations are:

- Size
- Shape
- Spin rate
- Spin state
- Orientation of angular momentum
- Whether the asteroid has a companion

To make a selection for maximum scientific return, we would like three asteroids that are as compositionally different as possible and best represent the major classes of asteroids, in other words we need taxonomic information.

The Data Currently Available: The data currently available are listed in Table 1. We identified forty trajectories that would each fly Hera to three asteroids and return samples to Earth using a Delta II launch vehicle and solar electric propulsion (Fig. 1). We list the asteroids that appeared in these trajectories and we give the number of times each appeared in the forty trajectories. Thus ignoring new NEA discoveries, there is a 16 out of 40 chance that 1993-BX3, for example, will appear in the final selection. We also list the physical and taxonomic data currently available: size can be estimated from magnitude and rotation rates are available for six, spectral classes are known for eight. Ten of the 20 will be observable in the next five years or so.

The Asteroid Candidates – Engineering Considerations: The main criterion for selecting asteroids from a mission design perspective is that the asteroid

Table 1. Target asteroids and data relevant to the Hera mission (Unpublished data from Leon Gefert, and ref. [5]).

Name	N*	Class	Size (m)	Absolute Magnitude	Rotation Period (h)	Next Observational Opportunity
1993-BX3	16	—	190-420	21	20.463	>10 y
2000-EA14	16	—	190-440	20.9	—	May 06
1989-UO	13	B	500-1100	19	7.733	Oct 03
(4660)-Nereus	12	XE	700-1500	18.2	—	Jun 04
1998-KY26	11	CO	<40	25.5	0.178	>10 y
(3361)-Orpheus	10	Q or V	500-1100	19	3.58	Oct 05
1998-VD32	9	—	100-240	22.2	—	Jul 07
2000-AG6	9	—	20-50	25.3	0.076	>10 y
1998-SF36	8	S(IV)	360	19.2	—	Jan 04
(10302)-1989-ML	5	X	370-840	19.5	—	Jan 06
2000-AF205	5	—	150-330	21.5	—	>10 y
1997-UR	3	—	70-160	23	—	>10 y
(4581)-Asclepius	3	—	250-560	20.4	—	>10 y
1993-PC	3	—	700-1500	18.3	—	—
1996-FG3	2	C	600-1400	18.4	—	Apr 09
2000-AH205	2	S_k	90-220	22.4	59±16.1	Jun 09
1999-AO10	2	—	50-110	23.9	—	>10 y
(6239)-Minos	1	—	800-1800	17.9	—	Jan 04
1998-HL3	1	—	300-670	20	—	Apr 04
2000-CH59	1	—	390-880	19.4	—	Jan 04

* N is the number of instances when the asteroid appears in forty independent trajectories involving visits to three asteroids

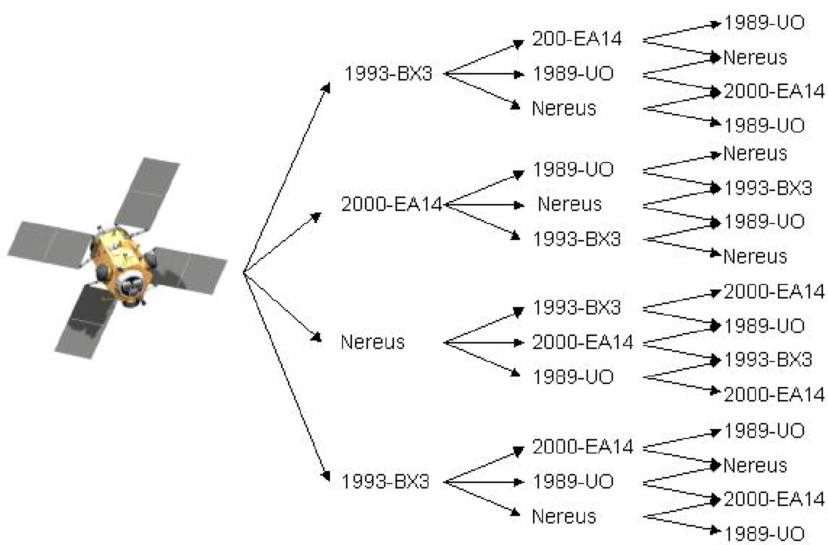

Fig. 1. The Hera mission will sample three near-Earth asteroids. For the twenty asteroids in Table 1 there are 40 possible missions and many additional trajectories have yet to be identified. The question is, which mission should we fly?

should not have a companion and that all three asteroids should require the same proximity operations. There is no evidence for companions for any of the asteroids in Table 1, but it seems very unlikely that companions are not present for some of them and we urge searches for them. We need rotation rate data for 2000–EA14, Nereus and 1998–VD32, and all the remainder, but 2000–AH205, especially for the asteroids high in the list. It is probably already clear that 1998–KY26 and 2000–AG6 should be dropped from the list of potential targets because they are fast rotators. Fast rotators might collide with the spacecraft and may need a different sampling strategy from the others due to the lack of loose regolith on their surface.

The Asteroid Candidates – Scientific Considerations: The only asteroid candidates for a mission are the asteroids for which classifications are known and this limits discussion to eight of the asteroids in Table 1 Even so this currently is an interesting list. We have two S asteroids, two C asteroids, a B asteroid, a Q/V asteroid, and two X asteroids [5].

The best known example of a B asteroid, like 1989–UO in our list, is the second largest asteroid, Pallas. B asteroids are related to C asteroids and their surface is probably composed of metamorphosed clay and opaque minerals.

S(IV) is the S subclass most closely resembling ordinary chondrites. The S(IV) asteroid 1998 SF36 is the MUSES C target. The asteroid 2000–AH205 is S_k class. These asteroids may represent a low pyroxene type of chondrite.

As one of the two major asteroid classes, perhaps related to the very important CI and CM chondrites that are rare on Earth, it seems essential that we include a C asteroid like 1996–FG3. C asteroids are thought to have clays, carbon and organics on their surfaces. They are a good candidate for new types of material because their rareness on Earth is probably related to their fragility.

The X asteroids have poorly understood featureless spectra and it is not clear what their scientific ranking should be. Samples would probably not help us understand the asteroid-meteorite link, but such asteroids might be the best source of new materials.

Asteroid Orpheus is either Q or V class. The Q class is a rare asteroid class whose spectra closely resemble those of ordinary chondrites, while the V class are basaltic material probably originating on Vesta, the fourth largest asteroid. The ambiguity over class would easily be resolved by returned samples, but this would not provide scientific justification for a mission to this asteroid.

Concluding Remarks: While the engineering or dynamic constraints on asteroid selection are very clear, choice of asteroid to maximize the science return is still a matter for discussion. It does already seem clear that a rich variety of scientifically rewarding targets are going to be accessible. In any event, before this discussion can be brought to a conclusion, we need to fill out Table 1 with data on both physical properties and taxonomic class for dynamically accessible asteroids. We have made good progress in the last year and there are many opportunities for further progress in the next few years.

Acknowledgement: We are grateful to Leon Gefert of Glenn Research Center for the trajectory calculations.

Reference: [1] D. W. G. Sears *et al.* (2001) *Eos Trans. AGU, 82 (47), Fall Meet. Suppl.,* Abstract P32B-0550. [2] J.A. Wood (2000) 33rd *Lunar Planet. Sci., Houston, TX.* [3] D. W. G. Sears *et al.* (2002). *Lunar Planet. Sci.* XXXIII, CD-ROM #1583. [4] D. W. G. Sears *et al.* (2001) *Meteorit. Planet. Sci.* **36**, A186. [5] R. P. Binzel *et al.* (2003) *Meteoriti. Planet. Sci.* (submitted). [6] M. J. Gaffy *et al.* (1993) *Meteoritics* **28**, 161.