Marco Polo –
A sample return mission from a Near Earth Object
(part of ESA’s Cosmic Vision programme studies)

Detlef Koschny, Marco Polo Study Scientist, the Science Study Team, and our Japanese colleagues

ESA/ESTEC, SCI-SM
Keplerlaan 1, 2200 Noordwijk, The Netherlands
Detlef.Koschny@esa.int

Cosmic Vision background
Target asteroids
Marco Polo technical status
Conclusions

Marco Polo Cannes Workshop, 05/06 Jun 2008
1. What are the conditions for life and planetary formation?

2. How does the solar system work?

3. What are the fundamental laws of the universe?

4. How did the universe begin and what is it made of?
From Themes to missions

2. How does the Solar System work?

Possible strategies

<table>
<thead>
<tr>
<th>Now and tomorrow</th>
<th>Cosmic Vision step 1</th>
<th>Cosmic Vision step 2</th>
<th>Further steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>What did the building blocks of our Solar System look like?</td>
<td>What was the original Solar System composition?</td>
<td>How does the Earth’s magnetosphere react to solar variations?</td>
<td>What was the detailed composition of primitive material?</td>
</tr>
<tr>
<td>Rosetta</td>
<td>Jupiter Exploration Programme</td>
<td></td>
<td>Near-Earth Object Sample Return</td>
</tr>
<tr>
<td>Which processes were dominant 4 billion years ago?</td>
<td>How do environmental interactions affect other planets?</td>
<td>Do solar magnetic field variations influence the Earth?</td>
<td>What happens at the frontier between the Sun’s empire and the interstellar medium?</td>
</tr>
<tr>
<td>BepiColombo</td>
<td>Venus Express</td>
<td>Earth Magnetospheric Swarm</td>
<td>Interstellar Heliopause Probe</td>
</tr>
<tr>
<td>How have atmospheres evolved?</td>
<td></td>
<td>Solar Polar Orbiter</td>
<td></td>
</tr>
<tr>
<td>Which processes affect the solar-terrestrial environment today?</td>
<td>Are there Earth-like exoplanets?</td>
<td></td>
<td>Do exoplanets differ from our own planet; if so, why?</td>
</tr>
<tr>
<td>Solar Orbiter</td>
<td></td>
<td></td>
<td>Terrestrial Planet Astrometric Surveyor</td>
</tr>
<tr>
<td>Is our Solar System unique?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Cosmic Vision – Missions and timeline

- The current studies prepare the final selection (in 2011) of two missions:
  - 1 medium “M” Mission
  - 1 large “L” Mission
- Available budget: ~ 950 M€.
Marco Polo

- Sample return from a *primitive* asteroid
- Collaboration with Japan
- Proposed by Antonella Barucci, Obs. Paris (+ ca. 400 scientists)
Science goals

Marco Polo = Sample return from a primitive Near-Earth Object (NEO)
(1) Origin of the solar system and the planets
(2) Formation and evolution of NEOs
(3) Astrobiology

More: See presentation by Antonella!
Current design according to CDF study

Assumption: Study complete mission with all elements

Mission requirements
- Return sample
- Place samples in their global and local context
- Provide complementary science results not achievable from the samples themselves

Science requirements
- Return >30 g (goal 100 g) of sample
- Context measurements are defined in detail

<table>
<thead>
<tr>
<th></th>
<th>Spatial resolution for imaging in the visual</th>
<th>Spatial resolution for VIS/IR spectrometer</th>
<th>Spatial resolution for mid-IR instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global characterisation</td>
<td>Order of dm</td>
<td>Order of m</td>
<td>Order of 10 m</td>
</tr>
<tr>
<td>Local characterisation</td>
<td>Order of mm</td>
<td>Order of dm</td>
<td>Order of dm</td>
</tr>
<tr>
<td>Context measurements</td>
<td>Tens of μm</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
## Target asteroid

### Candidate NEO Targets for Marco Polo

<table>
<thead>
<tr>
<th>Rank</th>
<th>Rank2</th>
<th>Rank3</th>
<th>Provisional designation</th>
<th>Number</th>
<th>Type</th>
<th>q (AU)</th>
<th>Q (AU)</th>
<th>i (deg)</th>
<th>Total analytical Delta V&lt;sup&gt;0&lt;/sup&gt;</th>
<th>Numerical v&lt;sub&gt;entry&lt;/sub&gt; (km/s)</th>
<th>HV</th>
<th>D (km) assumes p=0.05</th>
<th>Prot (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999 JU3</td>
<td>162173</td>
<td>Cg</td>
<td>0.96</td>
<td>1.42</td>
<td>5.9</td>
<td>5.29</td>
<td>&lt;12.2</td>
<td>19.2</td>
<td>0.70</td>
<td>7.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001 AE2</td>
<td>138911</td>
<td>T</td>
<td>1.24</td>
<td>1.46</td>
<td>1.66</td>
<td>6.02</td>
<td>&lt;11.8</td>
<td>10.9</td>
<td>0.86</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999 RG36</td>
<td>101955</td>
<td>B or C&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.9</td>
<td>1.36</td>
<td>5</td>
<td>6.12</td>
<td>&lt;13</td>
<td>20.81</td>
<td>0.37</td>
<td>2.146</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001 SK162</td>
<td>162998</td>
<td>T</td>
<td>1.01</td>
<td>2.84</td>
<td>1.7</td>
<td>0.91</td>
<td>17.77</td>
<td>1.52</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001 FC7</td>
<td>68278</td>
<td>Cy&lt;sup&gt;4&lt;/sup&gt;</td>
<td>1.27</td>
<td>1.5</td>
<td>2.0</td>
<td>7.2</td>
<td>&lt;12</td>
<td>18.17</td>
<td>1.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1939 UQ</td>
<td>65679</td>
<td>B</td>
<td>0.57</td>
<td>1.16</td>
<td>1.3</td>
<td>7.43</td>
<td>&lt;12.3</td>
<td>19.28</td>
<td>0.76</td>
<td>7.733</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1977 YA</td>
<td>155564</td>
<td>C or Xc&lt;sup&gt;4&lt;/sup&gt;</td>
<td>1.13</td>
<td>2.6</td>
<td>3</td>
<td>7.93</td>
<td>19.06</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001 SG286</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998 KU2</td>
<td>152879</td>
<td>CB</td>
<td>1.01</td>
<td>3.64</td>
<td>4.0</td>
<td>8.33</td>
<td>~15</td>
<td>20.93</td>
<td>0.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999 FG3</td>
<td>65679</td>
<td>C</td>
<td>0.95</td>
<td>1.42</td>
<td>2</td>
<td>8.35</td>
<td>~15</td>
<td>18.22</td>
<td>1.23</td>
<td>3.5942</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anza</td>
<td>2061</td>
<td>TCG</td>
<td>1.05</td>
<td>3.46</td>
<td>3.8</td>
<td>8.4</td>
<td>16.56</td>
<td>2.65</td>
<td>5.75, 11.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1979 VA = Wilson-Harrington</td>
<td>4015</td>
<td>Dormant comet</td>
<td>0.99</td>
<td>4.28</td>
<td>2.8</td>
<td>8.6</td>
<td>~15</td>
<td>15.99</td>
<td>3.44</td>
<td>3.56, 6.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991 DB</td>
<td>14412</td>
<td>C</td>
<td>1.03</td>
<td>2.41</td>
<td>11.4</td>
<td>8.79</td>
<td>18.4</td>
<td>1.13</td>
<td>2.266</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000 RW37</td>
<td>162567</td>
<td>C</td>
<td>0.94</td>
<td>1.56</td>
<td>13.7</td>
<td>8.99</td>
<td>19.74</td>
<td>0.51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998 UT18</td>
<td>85774</td>
<td>C</td>
<td>0.94</td>
<td>1.87</td>
<td>13.6</td>
<td>9.21</td>
<td>19.07</td>
<td>0.83</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Pre-selection of 15 targets already performed
- Main selection criteria is scientific value
  - 2001 SG286
  - 2001 SK162
  - 1999 JU3
  - 1998 UQ
- Second selection criteria is engineering feasibility, risk and cost
### Selected target

<table>
<thead>
<tr>
<th>NEO</th>
<th>Scientific return</th>
<th>Feasibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001 SG286</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2001 SK162</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1999 JU3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1989 UQ</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
Mission profile

Launch: 22 Sep 2017, Soyuz Fregate 2-1b
- Earth swingby 20 Sep 2018
- Venus swingby 05 Mar 2019

Arrival at asteroid 20 Dez 2020
- Science mission
Retirement Detlef 01 Apr 2022

Departure 18 Jul 2022
- Venus Swingby 25 Jun 2023
Arrival at the Earth 19 Nov 2023

Total duration: 6.2 Jahre
“Global characterisation”

- Far (1) – 5 km formation flying – 2 weeks
  - Measure size, shape, rotation period, axis orient.
  - Measure morphology in low-res, mineralogy
  - First mass estimate

- Gravity field (2) – 3 km terminator orbit – 4 weeks
  - Lowest disturbance

- Near (3) – 1.25 km orbit at 9 am – 8 weeks
  - Good illumination conditions for mapping
Science mission - II

“Local characterisation” – 5 weeks
- Descent to 100 m
- Do this for 5 potential sampling sites

“Sample context”
- Land and sample up to 3 sites
- Determine regolith properties before/after sampling
Spacecraft configuration
Asteroid Itokawa

Asteroid Eros

Itokawa images: JAXA; Eros: NASA

MP-RSSD-HO-008/1- 03 Jun 2008
Sampling

3 options were studied:
- Shovel
- Scoop
- Corer/grinder
Sampling

3 options were studied:
- Shovel
- Scoop
- Corer/grinder

Sampling & Transfer mechanisms units
- Rotary Corer (RC) with shutter
- Corer = Sample Vessel (3 x)
- Extendable Arm (EA) for sampling
- Corer Holder (CH) & Back Cover (BC) on Carousel (Car)
- Lift mechanism (LM) supports CH and BC on Carousel
- BC Lock
- Sample Container (SC)
Earth Return Capsule
Status

Class M missions: up to 300 MEuro
Class L missions: up to 650 MEuro

Advisory structure

Selection of 8 missions for study

2008
Feasibility studies
Present results to advisory structure 2 M, 2 L missions selected for definition study

2009
Industrial studies (two in parallel each) for 4 missions (2 M, 2 L)

2010
Presentation to advisory structure; selection of one mission each (1 M, 1 L) – confirm budgets, confirm payload

2011
Implementation phase in industry, launch ca. 2017

2012
Call for payload studies

Includes studies of curation facilities.