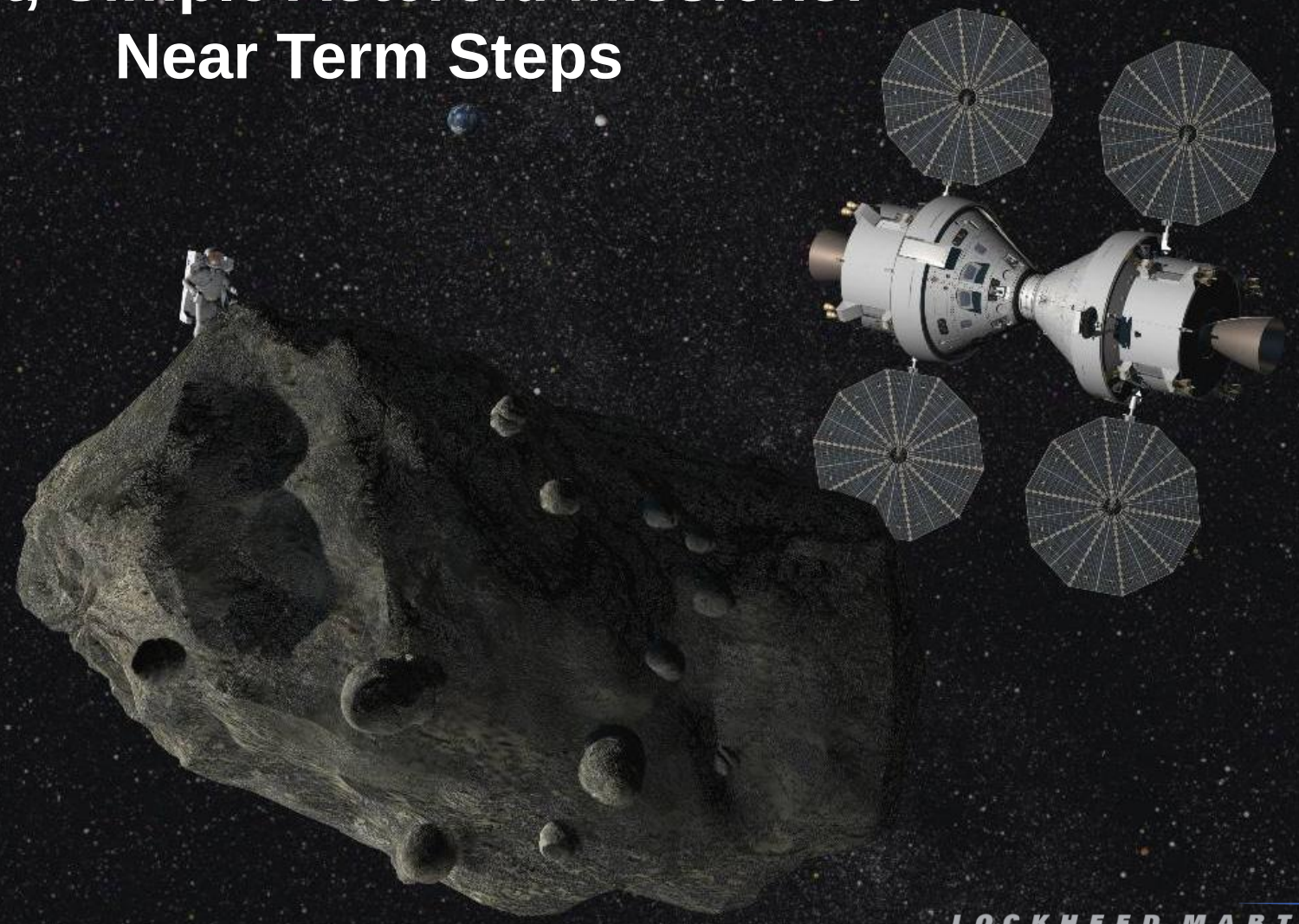
Short, Simple Asteroid Missions: Near Term Steps



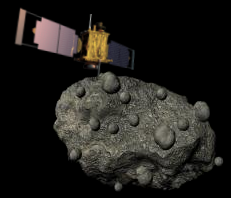
Josh Hopkins

Human Space Exploration Community Workshop on the Global Exploration Roadmap

November 14, 2011, San Diego

Stepping Stones

Stepping Stones is a proposed series of exploration missions building incrementally towards America's long term goal of exploring Mars. Each mission will address science objectives relating to the formation of the solar system and the origins of life.



2017
Asteroid scout

2018
Explore the Moon's far side from Earth-Moon L2 point

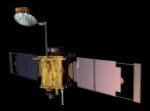
2016
Asteroid survey

2017
Lunar flyby, SLS test flight

Human systems extended duration tests on ISS

Dates subject to change

2023
Deimos Scout



2031-2035
Red Rocks: explore Mars from Deimos

2019, 2024, 2025, 2029
Plymouth Rock: Humans explore asteroid 2008 EA9, 2000 SG344, and others

A human mission to the moons of Mars will require capabilities such as heavy-lift launch, tele-operation of rovers from orbit, operating on a low-gravity body, long term cryo-propellant storage, and maintaining crew health during long-term deep space exposure. These capabilities will be developed and demonstrated through a series of Stepping Stones missions.

Deimos photo courtesy of NASA-JPL, University of Arizona

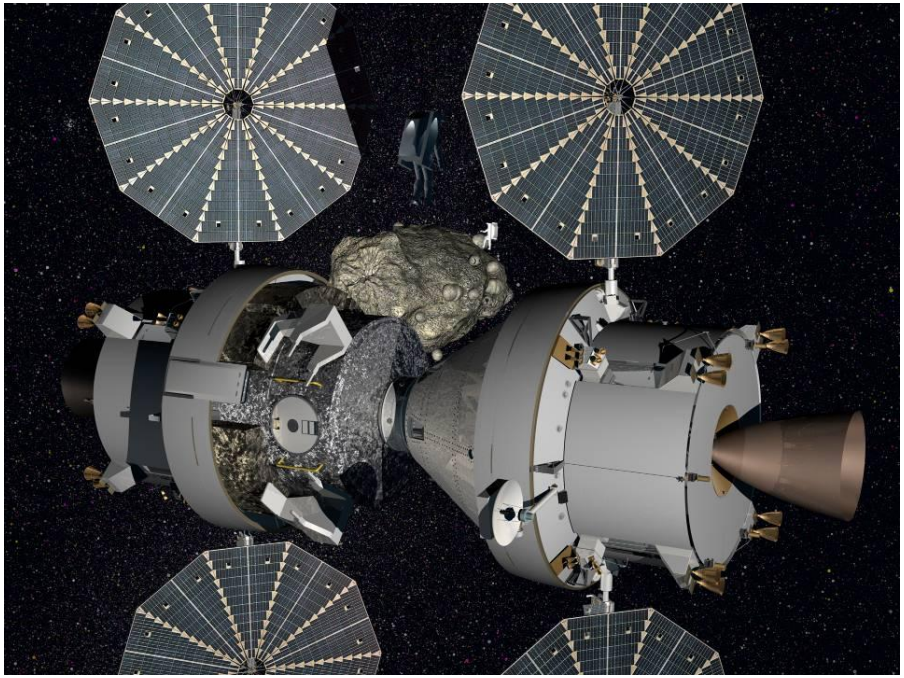
Keep Asteroid Missions Simple

- **Given fiscal constraints, deep space missions must be simple, affordable and productive in the near term if they are to happen at all**
- **Limiting human mission duration to 6-8 months is key to reducing complexity and cost**
  - **Short missions simplify or avoid problems of microgravity, radiation, closed loop life support, reliability/spares, etc.**
  - **Electric propulsion is not compatible with short mission durations**
- **The benefits of MMSEV don't appear to justify its added cost, mass, and complexity**
  - **However, a simpler unpressurized version might be necessary depending on details of dynamics around small bodies**

Two Possible Examples of Austere Missions

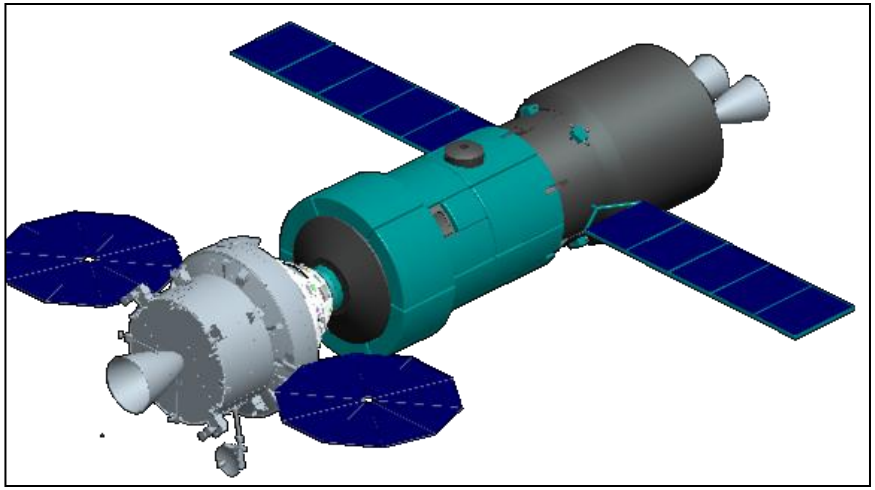
Plymouth Rock

- Two modified Orions, 1 SLS?
- ~45 tons to escape velocity
- 2 person crew (best case 3)
- 1.6-1.8 km/s ΔV capability
- 6-7 month max mission



Larger System

- 1 Orion
- 1 new Hab Module (ISS-sized)
- 1 in-space propulsion stage
- ~80-85 tons to escape velocity
- 3.2-3.7 km/s ΔV capability
- 3 person crew
- 2 launches on SLS?



Mission Opportunities 2019-2030

Asteroid	Launch Date	Diameter	OCC	Orbit Determination Opportunity	Mission Example		
					Spacecraft Delta V	Reentry Velocity	Duration
2008 EA9	Nov 2019	6-30 m	5	Oct 2019	1.6 km/s	11.16 km/s	200 d
2009 OS5	**Feb 2020**	**40-180 m**	**5**	**Faint late 2014**	**3.3 km/s**	**11.25 km/s**	**180 d**
2001 GP2	Apr 2020	10-40 m	6	Lost	3.5 km/s	11.34 km/s	180 d
2007 UN12	Jul 2020	5-20 m	4	Space-based	1.6 km/s	11.25 km/s	230 d
2011 CL50	Dec 2020	6-30 m	6	Jan 2016	2.9 km/s	11.18 km/s	180 d
2010 UE51	Sep 2023	5-20 m	2	Space-based	1.6 km/s	11.12 km/s	160 d
2001 QJ142	**Apr 2024**	**45-200 m**	**6**	**Mar, Nov 2012**	**3.2 km/s**	**11.31 km/s**	**200 d**
1999 AO10	Aug 2025	35-150 m	4	Faint Jan 2019	3.2 km/s	11.39 km/s	180 d
2008 JL24	Sept 2025	3-10 m	3	Lost	2.6 km/s	11.4 km/s	180 d
2009 HC	Oct 2025	20-100 m	4	Aug 2024	1.0 km/s	11.5 km/s	360 d
2003 LN6	Dec 2025	30-125 m	5	Faint May 2022	3.6 km/s	11.74 km/s	180 d
2006 RH120	Jul 2028	3-10 m	1	Faint July 2028	1.7 km/s	11.12 km/s	135 d
2009 CV	Mar 2029	30-130 m	3	Dec 2015	2.4 m/s	11.4 km/s	240 d
2000 SG344	**Jul 2029**	**20-110 m**	**3**	**May 2028**	**1.7 km/s**	**11.16 km/s**	**145 d**

- **OCC = Orbit Condition Code, measures accuracy of orbit determination. 0 = best, 9 = worst on log scale. OCC should be 0 or 1 before mission launch**
- **Orbit Determination column shows opportunities to improve orbit accuracy. A date indicates the asteroid will be visible to Earth-based telescopes. "Faint" means it won't be detected by routine asteroid tracking assets but might be with additional effort. "Space-based" means the target can only be seen before launch by new in-space telescopes. "Lost" means it can not be recovered before launch**

Near Earth Asteroid Population

Legend

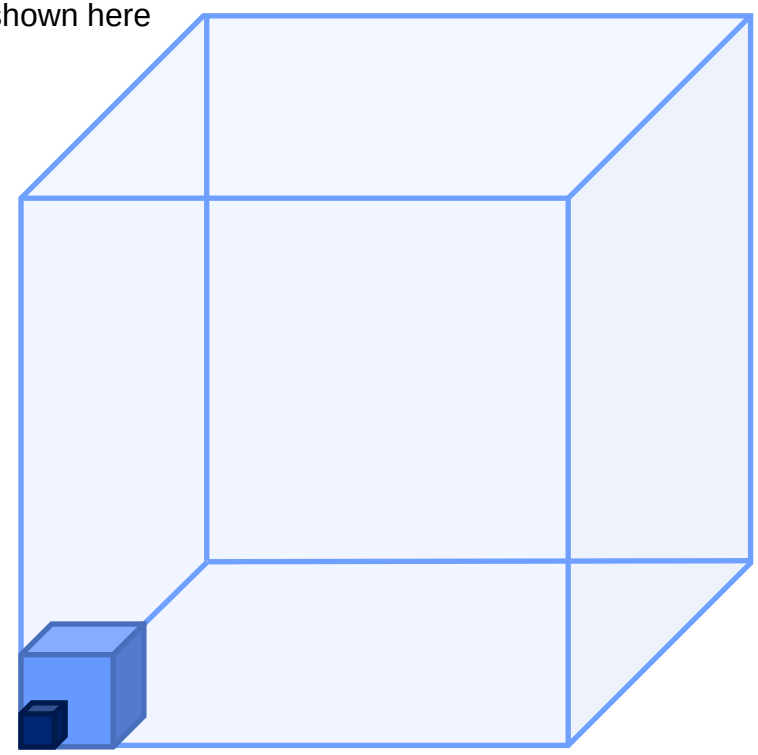
Scale Box = 1000 Asteroids

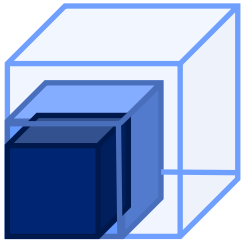
Clear = Predicted Population

Solid = Discovered Asteroids

Dark = Precision Orbit
(Orbit Condition Code ≤ 2)

Known asteroids as of Oct 2011
Population data from A. Mainzer/NEOWISE, Sept 2011
And A. Harris 2010
An additional ~1300 known asteroids are smaller than the ranges shown here





Size	**> 1 km**	**1 km to ~140 m**	**~140 m to ~30 m**
Magnitude	H < 17.8	H = 17.8 - 22	H = 22-25
# Known	~911 of ~981	4100 of ~12,500?	2000 of ~500,000?

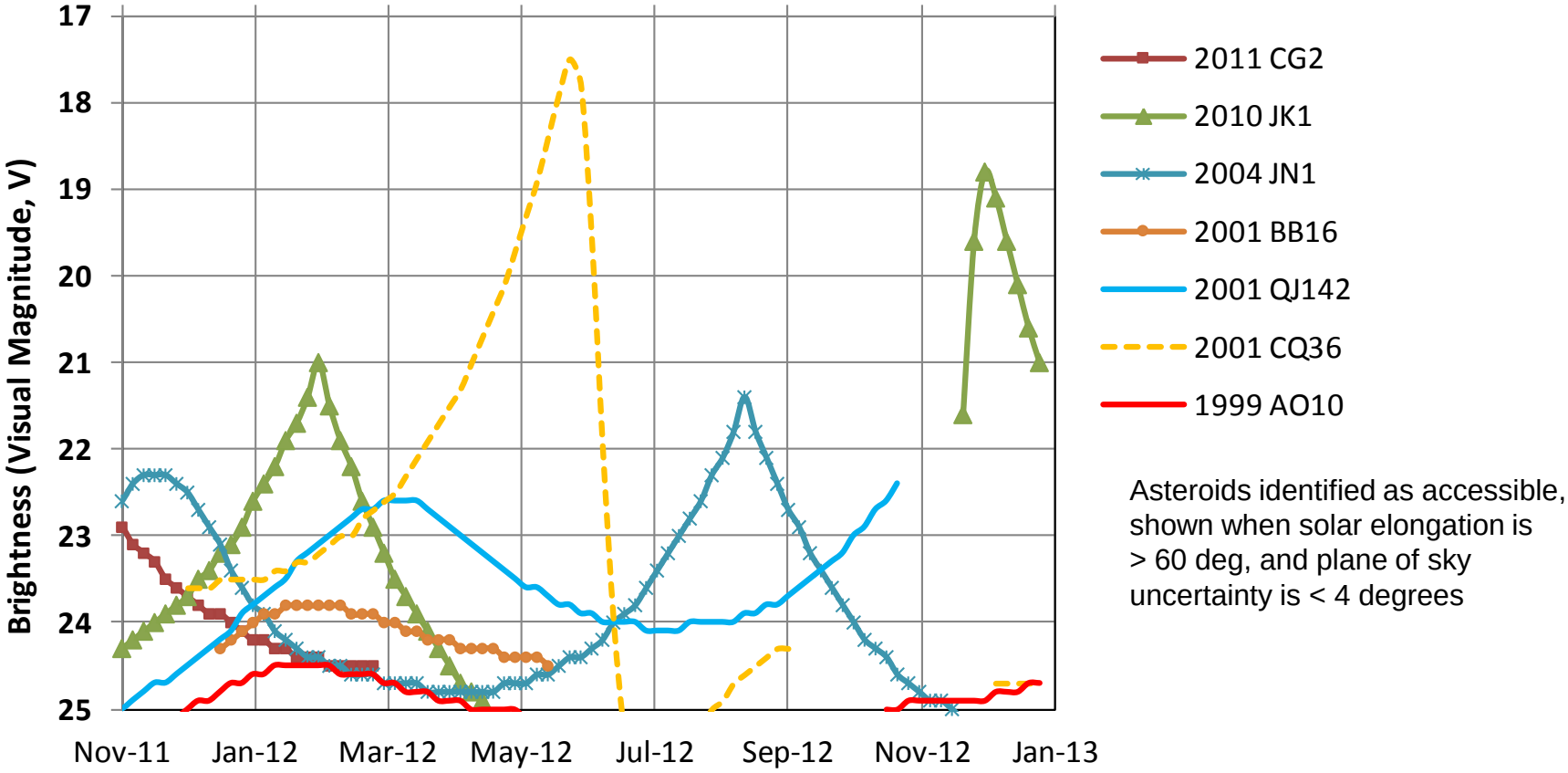
Discover And Track More Destinations

- **The most practical way to reach more asteroids is not to invest in better spaceships, but in better telescopes for surveys and tracking**
- **Things aren't getting better. Siding Springs Survey and La Sagra Sky Survey are winding down**
- **125 asteroids discovered so far this year (18%) have been observed for two nights or less. These and many others are lost.**
- **Lockheed Martin is working with astronomers to prioritize and coordinate astrometry and photometry so the most accessible asteroids won't be lost**
  - **Potentially Accessible Asteroids visible tonight are listed at http://www.HohmannTransfer.com/busy/camp/pmd_ephem.htm**

Available Tracking Capabilities

- Backyard observatories and small university telescopes in many countries are providing good astrometry of asteroids at 20-21.5 visual magnitude and photometry of brighter objects
  - Many of these efforts could be augmented for just thousands of dollars
- Dedicated asteroid tracking observatories (1-2 m telescopes) can typically see 22.5 V objects
- Existing large telescopes can see much fainter objects but are not often available to asteroid observers
  - Mauna Kea telescopes can recover asteroids at 23-24.5 V, but are usually allocated to other topics
  - More observing time is needed on large telescopes

Human-Accessible Asteroids Visible in 2012



Asteroids identified as accessible, shown when solar elongation is > 60 deg, and plane of sky uncertainty is < 4 degrees

- **We need to routinely recover asteroids fainter than 22 V (roughly the current routine limit), especially in the southern hemisphere**
- **We need more frequent access to telescopes that can see 24.5 V**

Near Term Asteroid Mission Enablers

- **Improved astrometry and photometry of known asteroids after discovery**
  - **Almost any industrialized country can make meaningful contributions at very small costs**
- **Improved asteroid discovery rate**
- **A precursor scout to characterize one or more asteroids smaller than the rubble-pile threshold (~150-200 m)**
  - **Don't wait to pick the one we think astronauts will go to**
  - **Most spacefaring nations could execute a mission like this**
- **Additional ground based biomedical research to understand the medical effects of cosmic rays**
- **Multiple astronaut stays on ISS longer than 6 months to understand long duration microgravity effects and mitigation**