

A deep space photograph showing a vast field of galaxies and stars against a black background. The galaxies are of various shapes and sizes, some appearing as bright, elongated streaks and others as more compact, spiral or elliptical structures. The stars are scattered throughout the field, with some showing prominent diffraction patterns. The overall scene is a rich, colorful representation of the universe's vastness.

# Asia's Road to the Moon, Mars, and Beyond

Dr. John S. Lewis, University of  
Arizona and Tsinghua University

# Why the Moon First?

Nearby – 400,000 km from Earth

Quick signal return – 1.3 seconds each way

Short travel time – 3 days each way

Accessible with existing GEO boosters



# What resources are available on the Moon?

- Oxygen in common FeO-bearing minerals:  
ilmenite, olivine, pyroxene
- Water ice in unknown abundance at poles
- Ferrous metals
  - Fe-Ni alloy from asteroid impacts
  - Fe from reduction of FeO by solar wind  $H_2$
- $^3He$  fusion fuel from solar wind implantation

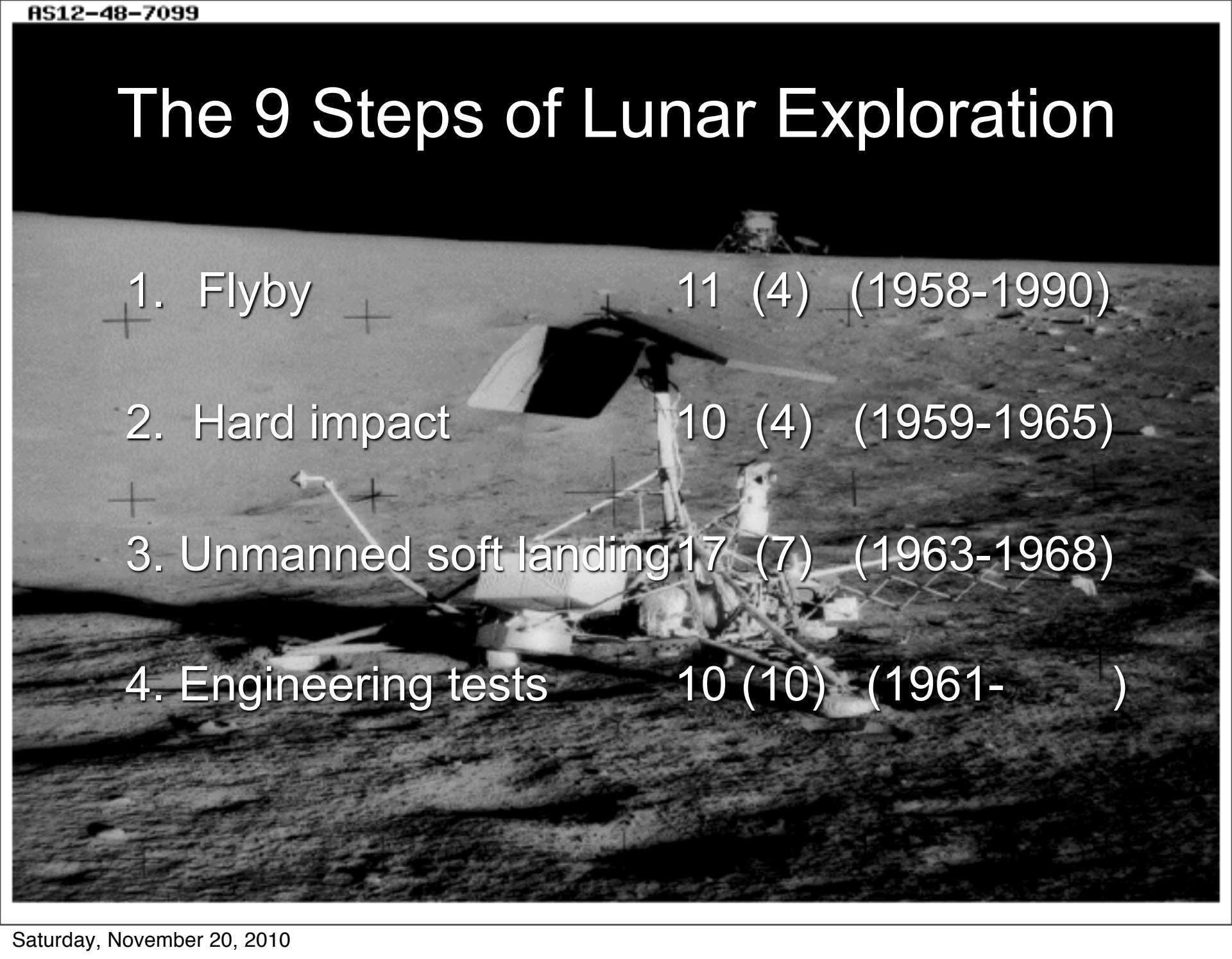
# Progress in Exploring the Moon

A photograph of a rocket launch, likely the Chinese Chang'e 2 mission, showing the rocket ascending with a massive, bright orange and yellow plume of fire and white smoke trailing behind it. The launch is taking place against a clear blue sky. The rocket is white with some red and black markings. The launch pad and some support structures are visible at the bottom of the frame.

- 88 lunar missions launched (63 successes) by USSR, USA, ESA, Japan, China, and India
- 9 steps of lunar exploration:



# The 9 Steps of Lunar Exploration

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1. Flyby 11 (4) (1958-1990)
  2. Hard impact 10 (4) (1959-1965)
  3. Unmanned soft landing 17 (7) (1963-1968)
  4. Engineering tests 10 (10) (1961- )

# The 9 Steps of Lunar Exploration

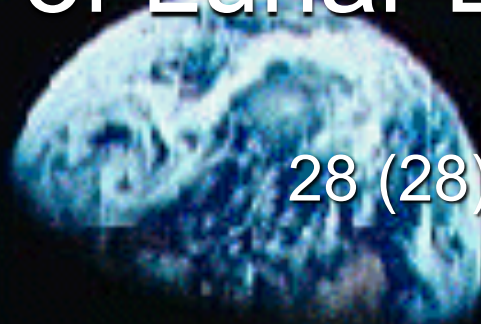
5. Lunar orbiters 28 (28) (1966- )

6. Unmanned rovers 2 (2) (1970-1973)

7. Unmanned sample return 6 (3) (1969-1976)

8. Manned landings 7 (6) (1969-1972)

9. Lunar base 0





# Recent Lunar Missions

(2004-2010)

2007	China	<i>Chang'e 1</i> lunar orbiter
2007	Japan	<i>SELENE</i> lunar orbiter with surface penetrator probe
2008	USA	<i>Lunar Reconnaissance Orbiter</i> with polar ice probe
2008	India	<i>Chandrayaan</i> orbiter
2010	China	<i>Chang'e 2</i> lunar mapper



# Planned Lunar Missions

- 2011 USA GRAIL orbiter
- 2013 China Chang'e 3 lander & rover
- 2013 India Chandrayaan 2 orbiter; lander & rover
- 2013 USA LADEE orbiter
- 2015? Japan Selene 2 orbiter, probes
- 2017 China Chang'e 4 sample return
- 2019 ESA Lunar Lander polar landing
- ~2025 China and India manned landings





# Capabilities of Existing Boosters

- China CZ-3A Mars probe 2013  
Venus Probe 2015
- India ASLV Mars/Venus ----
- Japan M-V-3 Mars/Venus ----  
H-2A too expensive?
- Russia Zenit/Fregat Phobos  
Proton “too expensive to use”



# Larger Boosters Needed: China

## Next-generation boosters:

- CZ-5 25 t to LEO, 8 to GEO, Moon, Mars  
Saturn 1, Proton, STS payload capacity
- CZ-6 lightweight 2<sup>nd</sup>-generation launcher
- CZ-7 medium 2<sup>nd</sup>-generation launcher
- CZ-8 3 clustered CZ-5s: 25 t to escape
- CZ-9 5 clustered CZ-5s: 40 t to escape  
“Nova class”



# Availability/Use of Large PRC Boosters

Booster	Test Flight	Missions
• CZ-5	2014	Moon Sample Return- 2017 Testing Manned Lunar Lander in LEO Launch Space Station Core Module- 2020
• CZ-8	2020?	Manned Lunar Flyby
• CZ-9	2024	Manned lunar landing
2025		Direct Ascent, LOR, EOR?



# Men on the Moon: A New Space Race?

India and China have the Moon in their sights



# Progress in Exploring Mars



- 41 Mars missions launched  
(20 successes)
- 7 steps of Mars exploration



# Why go to Mars?

- **Most Earth-like planet: most user-friendly**
- **Once had abundant water**
- **Life may have begun on Mars**
- **Fossils, even life, may be present now**
- **Rockets can deliver more to Mars than to the Moon**

# Accessibility of Mars with Existing Boosters

- Flyby, orbiter and probe missions in the several-tonne class can be carried by GEO comsat launchers:

Russia	Soyuz 2/Fregat; Proton
USA	Atlas V, Delta 2
China	CZ-3C
India	ASLV
Japan	M-V-3; H2A
ESA	Ariane 5



# Resource Targets on Mars

- Rocket propellants from the atmosphere:  
CO and oxygen from CO<sub>2</sub> cracking
- Life support materials from ice and permafrost
- Phobos and Deimos similar to carbonaceous meteorites— for propellants and life support
- Mars' only promising export: Scientific samples



# 7 Steps of Mars Exploration

The background of the slide is a high-resolution photograph of the Martian surface. It shows a vast, flat landscape of reddish-orange sand and soil, dotted with numerous dark, angular rocks of various sizes. The horizon is visible in the distance under a hazy, pinkish sky.

1. Flyby	10 (3)	(1960-1969)
2. Lander	12 (4)	(1971- )
3. Orbiter	17 (11)	(1971- )
4. Rover	4 (3)	(1996- )



# 7 Steps of Mars Exploration

## - Future Steps -

5. Sample return 0

6. Manned landing 0

7. Mars base 0





# Recent Mars Missions

2000-date

- Mars Odyssey  
2001 USA Orbiter failure
- Spirit (MER-A) USA Rover 2003
- Mars Express  
Beagle 2 ESA Orbiter 2003  
UK Lander failure  
(Launch: Baikonur/Soyuz 2-Fregat)
- Opportunity (MER-B)  
Rover 2003 USA
- Mars Reconnaissance (MRO) USA Orbiter 2005
- Phoenix USA Lander 2007

# Planned Mars missions

- *Phobos-Grunt* Phobos lander/  
sample return; Russia 2011  
Carries *Yinghuo-1* orbiter China 2011
- Curiosity/MSL rover USA 2011
- MAVEN orbiter (atmosphere) USA 2013
- Mars Probe China 2013?
- Mars Probe India 2013/15
- Exo-Mars (exobiology) ESA/USA 2015



# Nations Expressing Interest in Manned Mars Exploration

- USA
- ESA member states
- Russia
- Japan
- China
- India

# Exploration of Mercury

- **Only 2 missions flown, both by NASA:**  
**Mariner 10 (MVM): 3 Mercury flybys**  
**Mercury Messenger: orbit insertion Jan. 2011**
- **Showed conditions to be:**
  - **Similar to the Moon but much hotter**
  - **No air or water; some polar ice**
  - **Covered with craters**

**Planned mission: ESA/JAXA BepiColombo orbiter, launch 2014, Mercury Orbit Insertion 2020**



# Why Explore Asteroids?

- Easy to get to
  - Many NEAs easier to land on than the Moon or Mars
  - Easier to return from than the Moon or Mars
  - Daily launch opportunities
- Untold riches (see next slide)
  - Metals, building materials
  - Water for life-support, oxygen, propellants
- Some are a threat to Earth – we could turn a liability into an asset

# What Resources are present on an Asteroid?

- Abundant ferrous metals
- Chemically bound water and buried ice
- Other volatiles for life support: C, N, S,...
- Many precious and strategic metals that are very rare on Earth are accessible



# Three Visited Asteroids



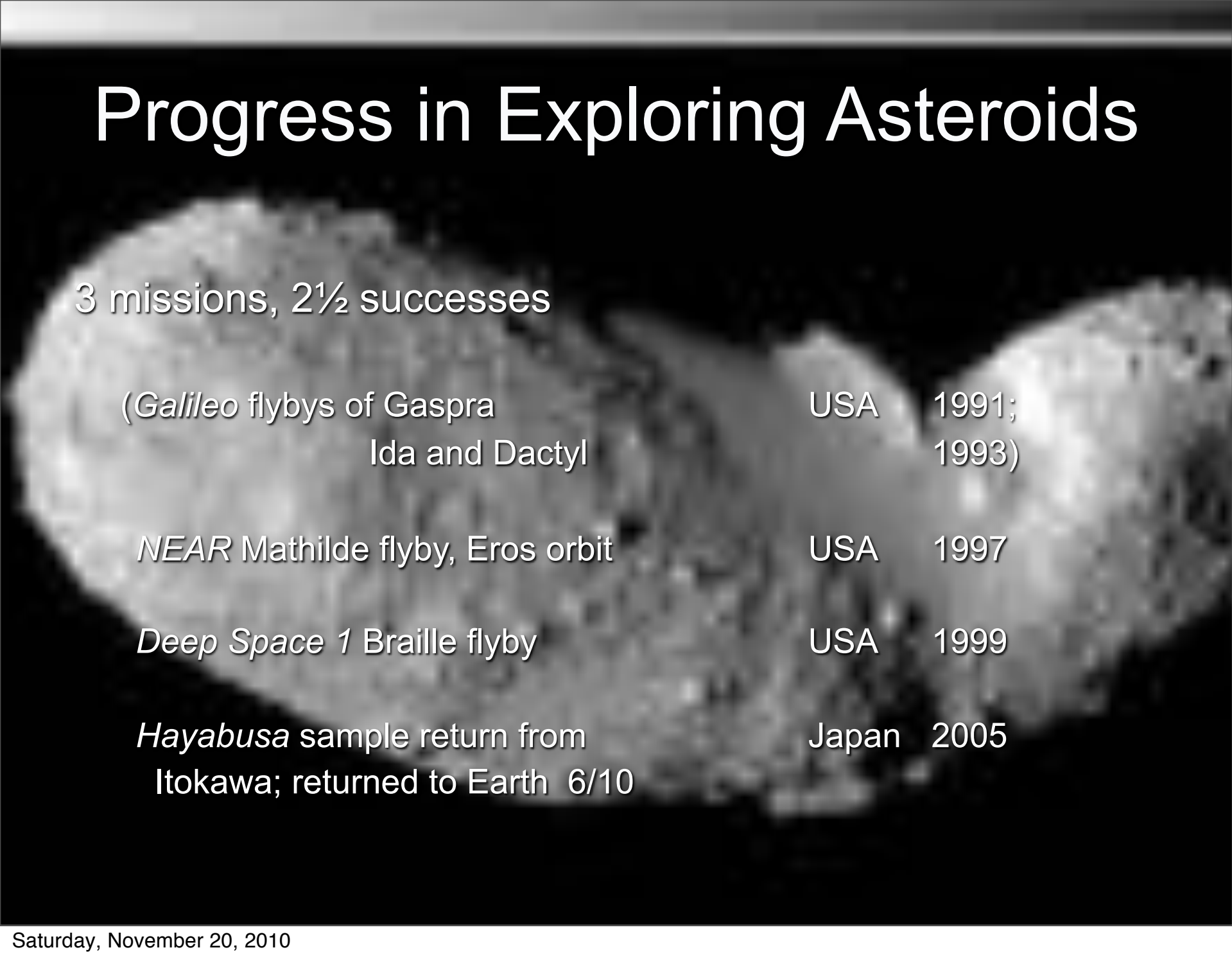
**Mathilde**



**Gaspra**



**Ida**



# Progress in Exploring Asteroids

3 missions, 2½ successes

( <i>Galileo</i> flybys of Gaspra Ida and Dactyl)	USA	1991; 1993)
<i>NEAR</i> Mathilde flyby, Eros orbit	USA	1997
<i>Deep Space 1</i> Braille flyby	USA	1999
<i>Hayabusa</i> sample return from Itokawa; returned to Earth 6/10	Japan	2005

Saturday, November 20, 2010

# 3 missions, 2½ successes

(*Galileo* flybys of Gaspra  
Ida and Dactyl)

USA 1991;  
1993)

## NEAR Mathilde flyby, Eros orbit

USA 1997

# Deep Space 1 Braille flyby

USA 1999

## Hayabusa sample return from Itokawa; returned to Earth 6/10

# Japan 2005



# Asteroid Exploration Plans

2011	Russia + China	<i>Phobos-Grunt</i> lander on asteroid-like Mars satellite with sample return to Earth
2013+?	Japan	<i>Hayabusa 2</i> sample return: Funding limits seem to preclude H2A booster use; partner sought



# Human Exploration Prospects – Part 1

- ☞ Manned missions to land on Mercury are very difficult and probably will not be done
- ☞ Manned missions to land on Venus are impossibly difficult



# Human Exploration Prospects – Part 2

- 👍 Moon: will resume before 2025, but US will not join the race
- 👍 Mars: first manned trip by US before 2025?
- ? The new kid on the block: Nearby asteroids.  
Flight test of Mars-bound manned spacecraft  
Resource assessment of selected NEAs  
Preparation for Planetary Defense missions



# The Mission that Might Have Been:

2004-5 Moon-Mars Phase A study

About 12 competing contractor teams

Raytheon team: John Lewis, Chair,

with Tom Jones batting cleanup

Briefing for Program Manager at NASA

Proposed inclusion of NEAs in plans for  
manned Mars missions

Manager:

“Asteroids have been baselined out.”

I asked: “By whom? Why?” No answer.

Mike Griffin didn’t know either...

We were excluded from Phase B because we  
“were not responsive to NASA’s priorities.”



# Prospects for International Cooperation- 1

- China and Russia are actively cooperating on lunar and planetary missions
- China has purchased airlock and space suit technology from Russia
- China and ESA have had cooperative Earth-orbiting missions (*Double Star*, etc.)
- India has flown US and ESA instruments on *Chandrayaan 1*; will continue to do so



# International Cooperation- 2

- China is still rankling over ISS issues
- Manned Mars missions are so expensive that sharing the work and cost is wise
- India plans manned spaceflight before 2015— whose technology base?
- China-India collaboration unlikely for political/prestige reasons
- Khrushchev's Law



# Some Tentative Conclusions

- India has a goal; China has a plan
- Resource interest in China and Japan extends to lunar  $^3\text{He}$ — and no farther
- Space colonization is not on the table for either China or Japan
- Chinese manned space is a function of the PLA: all flight, launch, and command functions are filled by active-duty military
- It IS a space race— politically and PR-driven



# The Good News

The Solar System and its riches are not being coveted by any government.

Private economic initiative has an opening and does not compete or conflict with ANY stated governmental ambitions.

The sky is no longer the limit.