Briefing to National Space Grant Directors

PLANETARY RESOURCES™

Chris Lewicki
President & Chief Asteroid Miner
@interplanetary

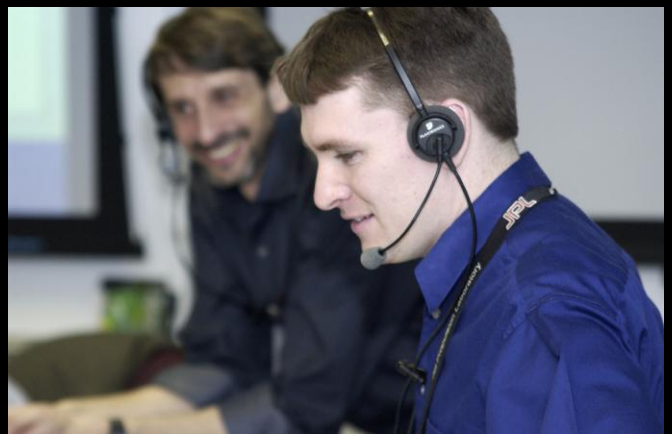
October 2012

From Student to the Solar System

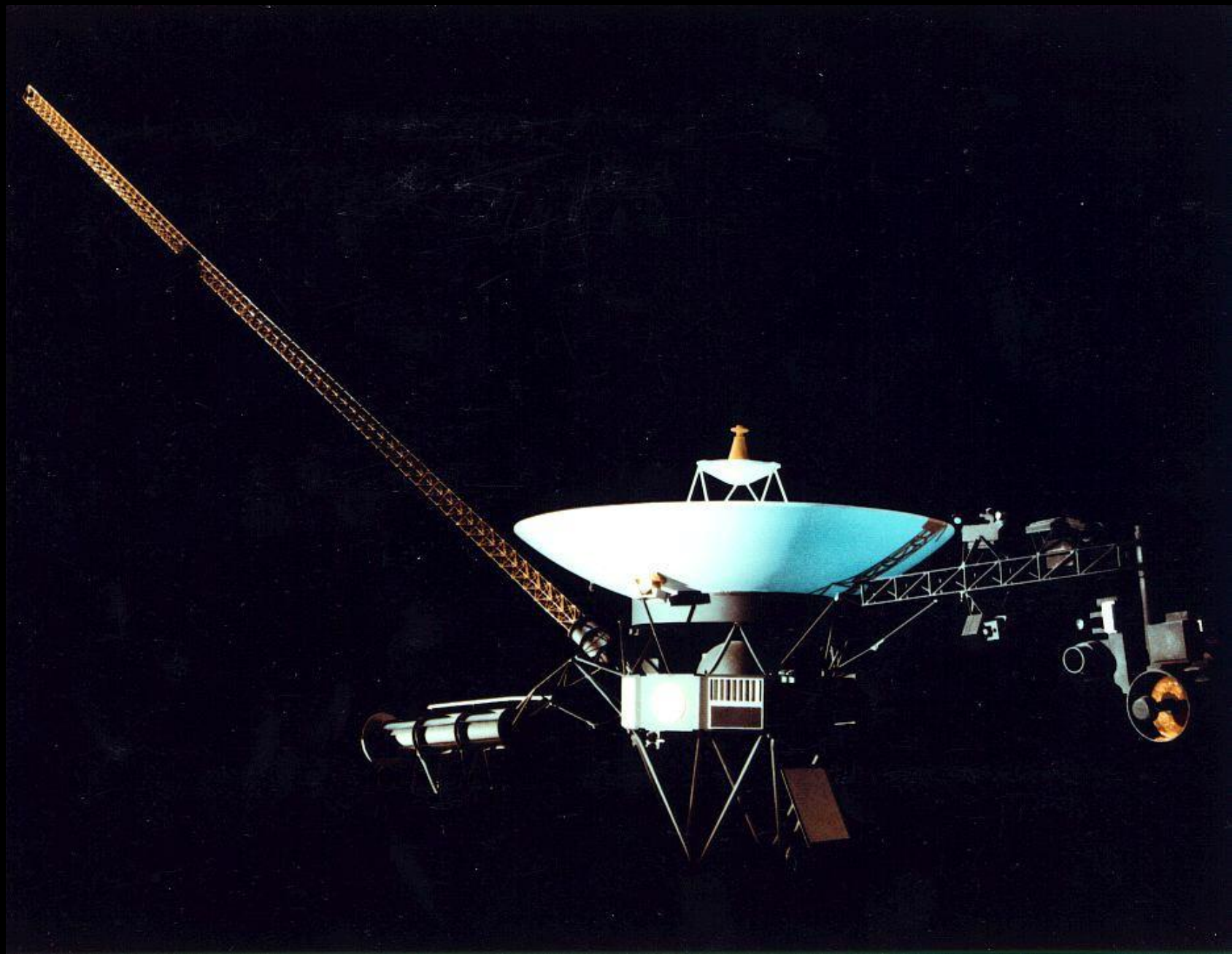
Chris Lewicki

President & Chief Asteroid Miner
Planetary Resources, Inc.

Phoenix Mars Scout
Flight Systems Engineer &
Lead Mission Manager



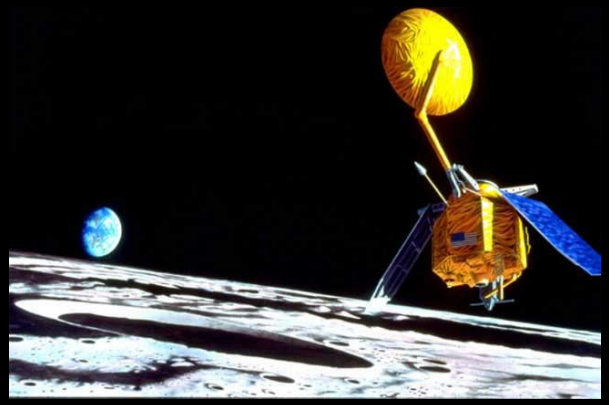
In the beginning…



Students for the Exploration and Development of Space

SEDS

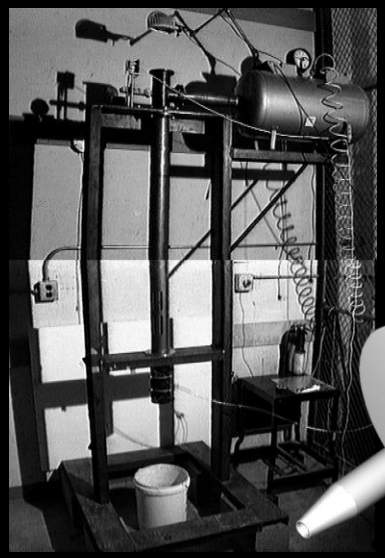
Proposals and Research

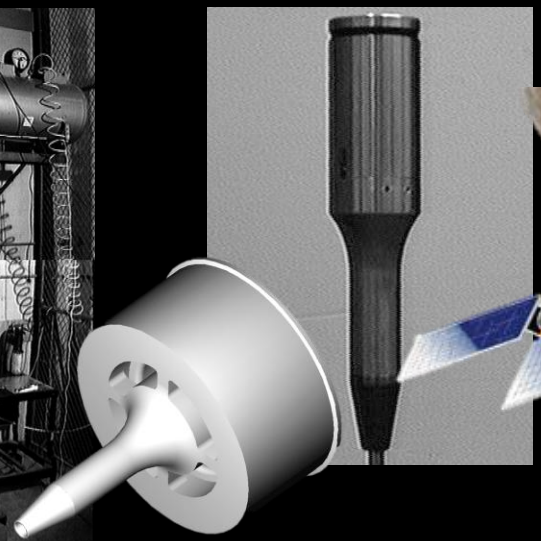


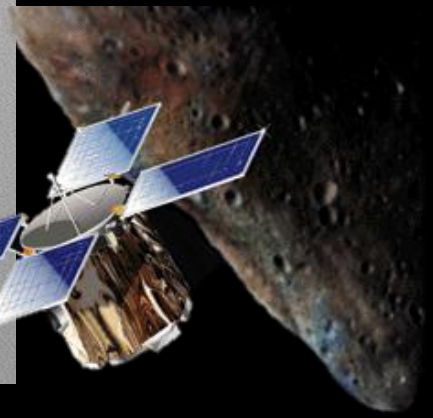
ARIZONA SPACE GRANT CONSORTIUM

Traveling to Mars

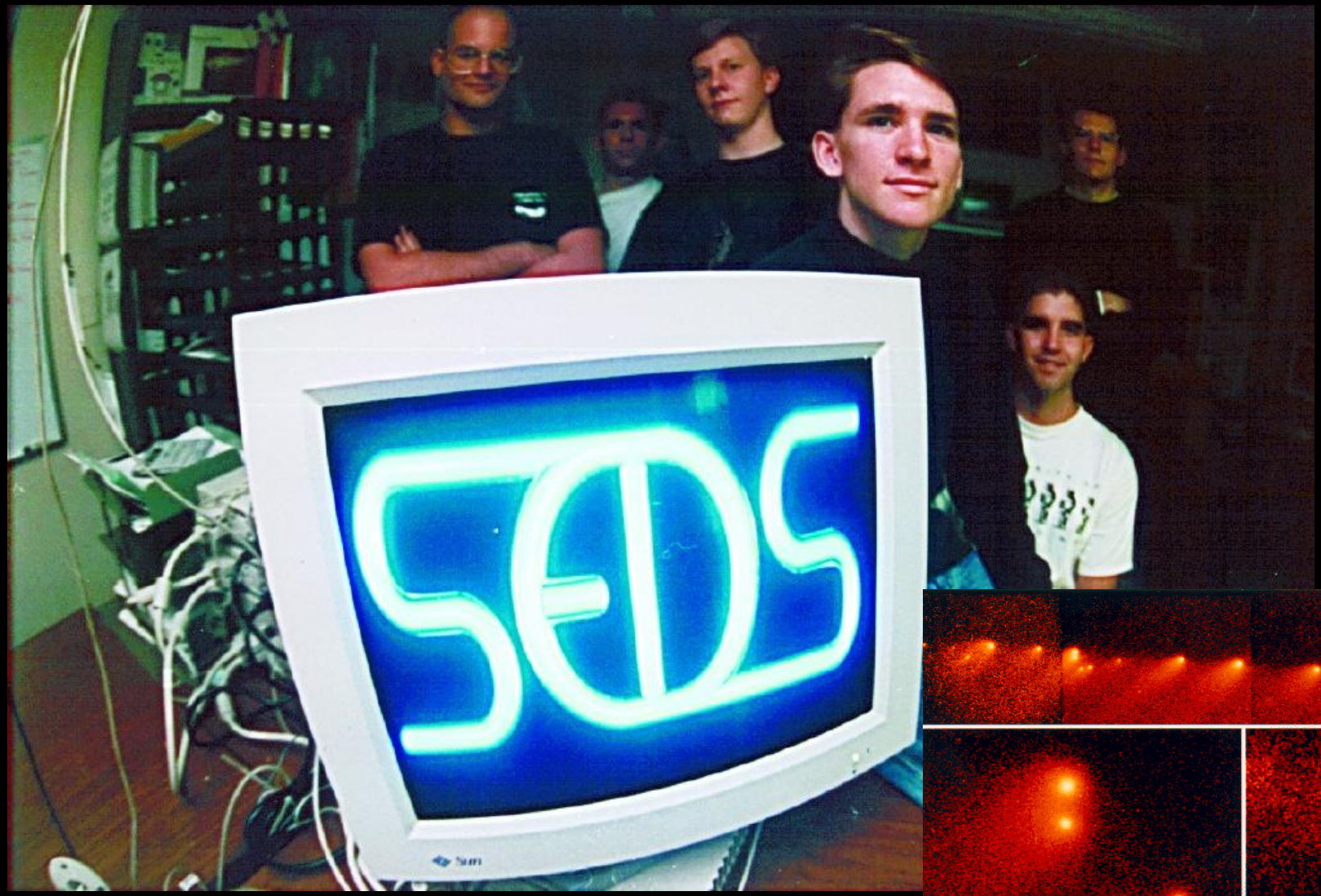
Comets and Asteroids

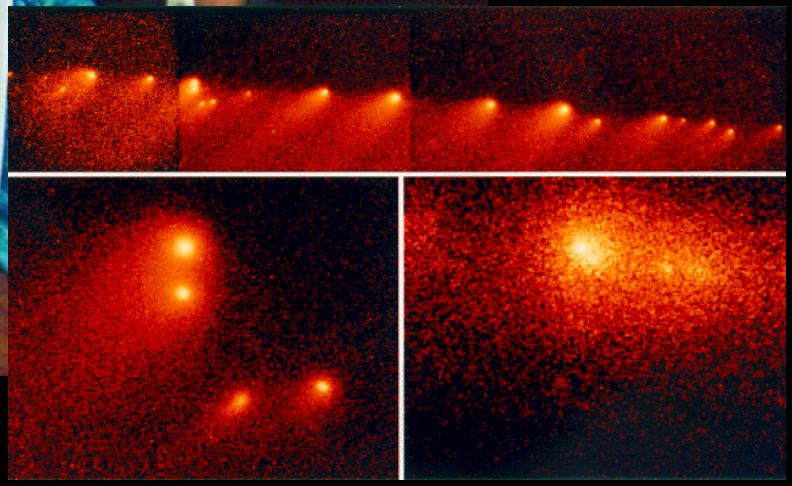






Space, Computers and the Internet





Testimony to Congress - Spring 1995
Space Sub-Committee of House Committee on Science

Introduction

One of the goals outlined in the Discovery mission Announcement of Opportunity was that of exciting and involving the students and citizens of this Country. Dr. Boynton's proposal had two unique approaches to this which I will briefly outline here.

GRAVITY SUBSATELLITE

Our proposal's gravity subsatellite was based on a design for an Earth orbiting amateur satellite, SEDSAT, which was designed, built, and is soon to be flown aboard the shuttle by the SEDS group from the University of Alabama at Huntsville.

Direct Student Operation of Spacecraft

Another approach for involving students allows the direct control of the spacecraft by the students themselves. During the last quarter of the mission, we would go through a month of "Driver's Ed" to become familiar with the operation of the spacecraft. When the mission had reached the end of it's NASA funded lifetime, Dr. Boynton would, in a sense, "turn the keys of the spacecraft" over to the students who would operate their own mission until ~~[illegible]~~ internal funds or spacecraft fuel run out -- whichever came first.

These are just a few specific examples of the many opportunities that NASA space science can offer students.

X Prize

The X Prize

Enabling human ingenuity and adventure in space

Intro | Volunteer!

Aviation Prize History

The X Prize: A Space Prize

Rules of the Game

Question & Answer | Feedback | Conclusion

Please fill out the X Prize *Rapid Space Tourism Survey*

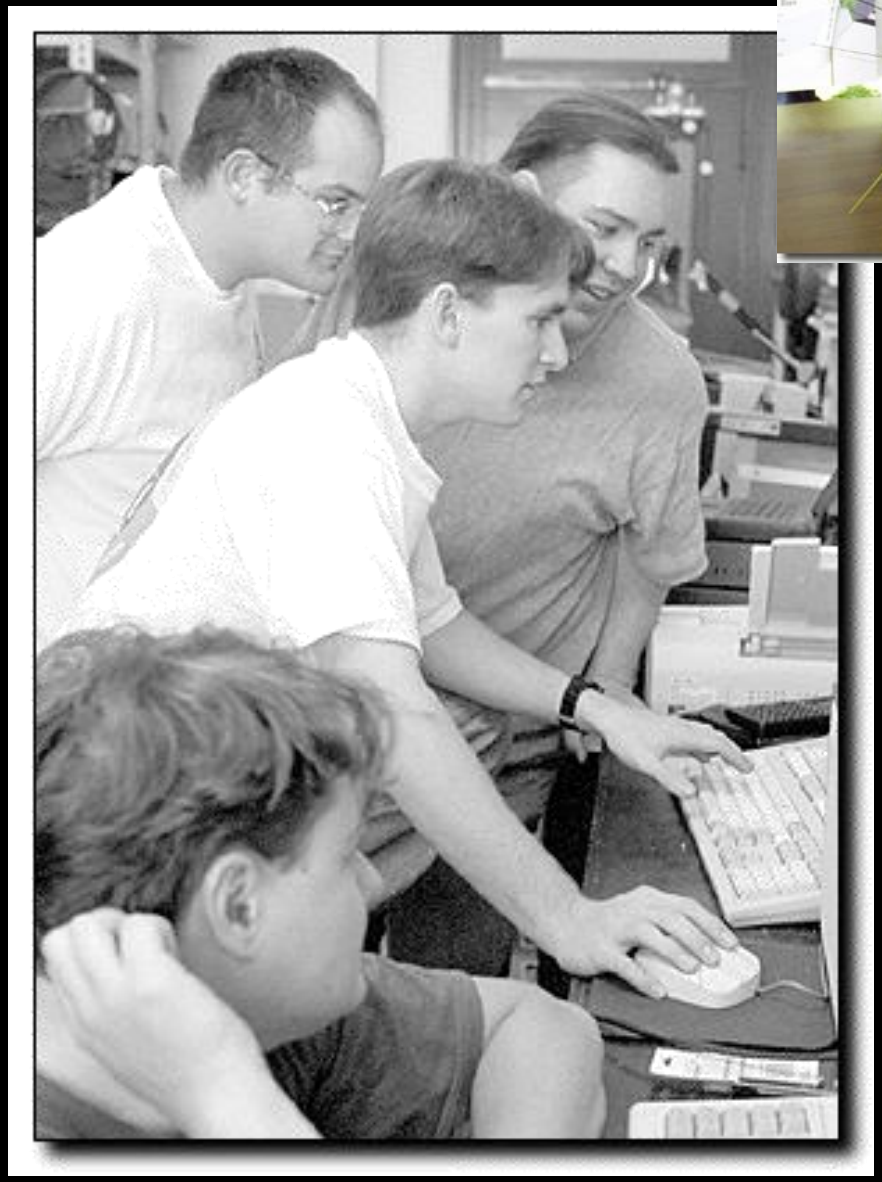
Introduction | Aviation Prize History | A Space Prize | Question & Answer | X Prize Rules | The X Prize Committee | Conclusion | Rapid Space Tourism Survey | Contact Information | More Info/Volunteer

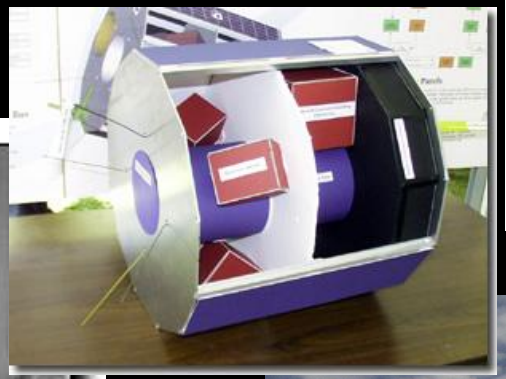
We welcome your feedback.

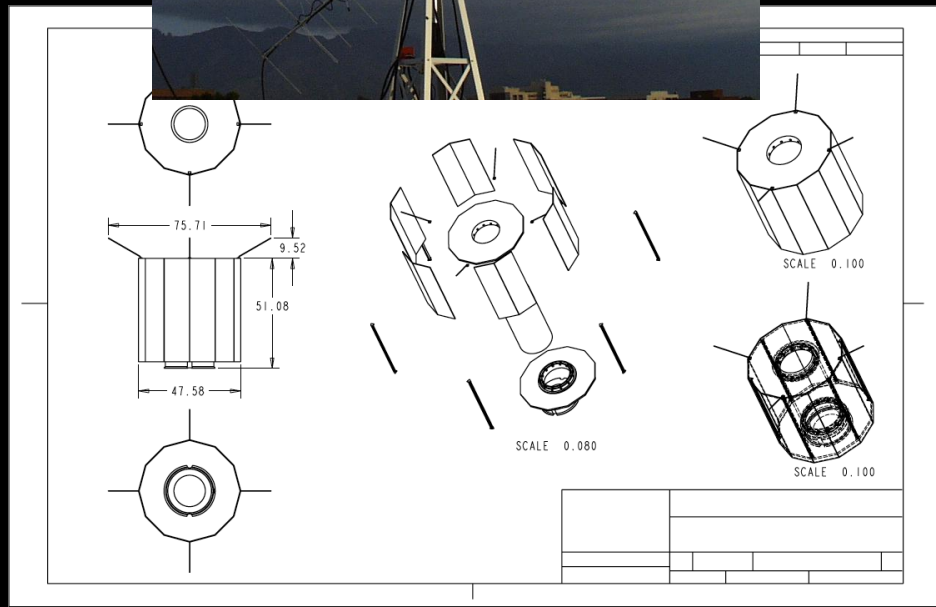
"We want to explore the use of prizes, which have been used in the West since the late Seventeenth Century and have had a big impact... We want to explore the use of prizes where, if we have a goal we want to achieve, let's set up a prize and whichever entrepreneur gets there first gets the money." Newt Gingrich, 1995

NASA Academy, GSFC 1996

Student Satellites







Roving on Mars – The first step is a big one!

Airbags


240
GENESIS
STARDUST
UNIVERSITY OF WASHINGTON
DEEP SPACE 1
NASA

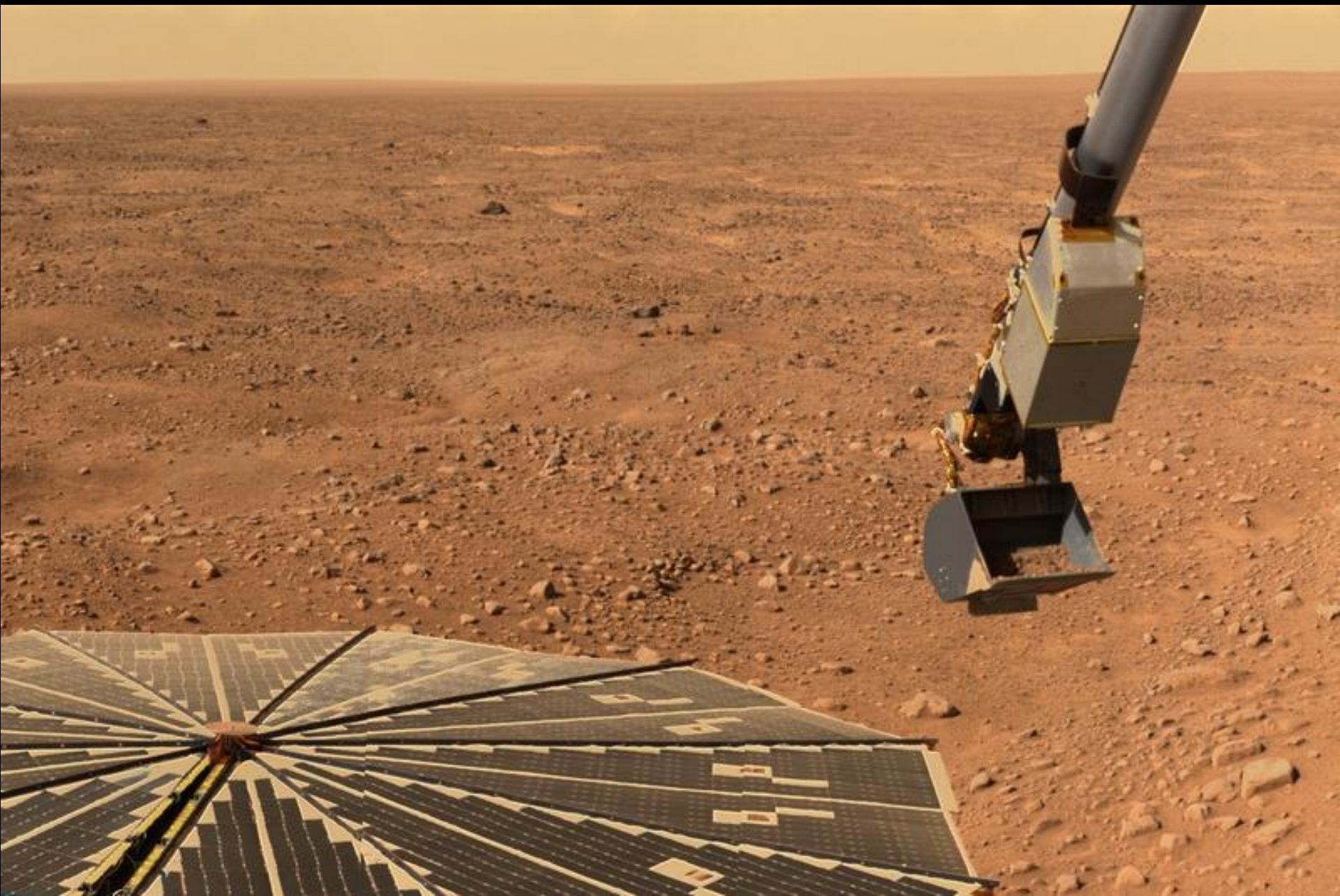
Launch Complex 17A, Level 9

January 3, 2004

My favorite picture… ever.

Phoenix Lander

My second favorite picture…



Time Magazine - "Verbatim", February 2004

Mission and Vision

Planetary Resources will bring the Solar System

within humanity's economic sphere of influence, and

expand the resource and real estate industries

beyond Earth.

Compelling Purpose. Executable Plan. Committed People. Empowered Public.

PLANETARY RESOURCES™

Why asteroids? Why now?

Planetary Resources was started because existing and projected technology made accessing resources from Near Earth Asteroids viable.

We are pursuing this business for two primary reasons:

1. *This offers the opportunity for huge financial returns*
2. *These resources are critical to humanity's continued growth both on Earth and beyond*

Founding Leadership

Eric C. Anderson

Co-Founder, Co-Chairman

Mr. Anderson is the entrepreneur who is widely credited with starting the commercial human spaceflight industry as co-founder and CEO of Space Adventures. He has served as the Chairman of the Commercial Spaceflight Federation, and is a Young Global Leader of the World Economic Forum. Mr. Anderson graduated magna cum laude with a B.S. in Aerospace Engineering from the University of Virginia.

Peter H. Diamandis, MD

Co-Founder & Co-Chairman

Dr. Diamandis is a pioneer in the commercial space arena, having co-founded Space Adventures, Zero-G and Int'l Space University. He is Chairman and CEO of the X PRIZE Foundation and the Executive Chairman of Singularity University. Diamandis has engineering degrees from MIT and an MD from Harvard. He is author of New York Times best seller ABUNDANCE.

Board of Advisors

James Cameron
Film director, producer,

Gen. Michael Moseley
Chief of Staff, Air Force (Ret.)

Dr. Thomas D Jones
Scientist, NASA astronaut

Dr. Sara Seager
MIT, Planetary Science

David Vaskevitch
Microsoft CFO (fmr)

John K Villa
Williams & Connolly Partner

Dr. Mark Sykes
Planetary Science Institute Director

Matthew Grob
Qualcomm CTO

Compelling Purpose. Executable Plan. Committed People. Empowered Public.

PLANETARY RESOURCES™

"Planetary Resources is definitely a great example of 'Having a healthy disregard for the impossible.' "

Larry Page

"The pursuit of resources drove the discovery of America and opened the west. The same drivers still hold true for opening the space frontier. I'm involved with Planetary Resources Corporation because expanding the resource base for humanity is important for our future."

Eric Schmidt

"I am an investor in Planetary Resources, first and foremost, because I believe in the team behind it. I'm honored to be on the ground floor with a team that possesses this caliber of expertise, vision, drive and history of success."

H. Ross Perot, Jr.

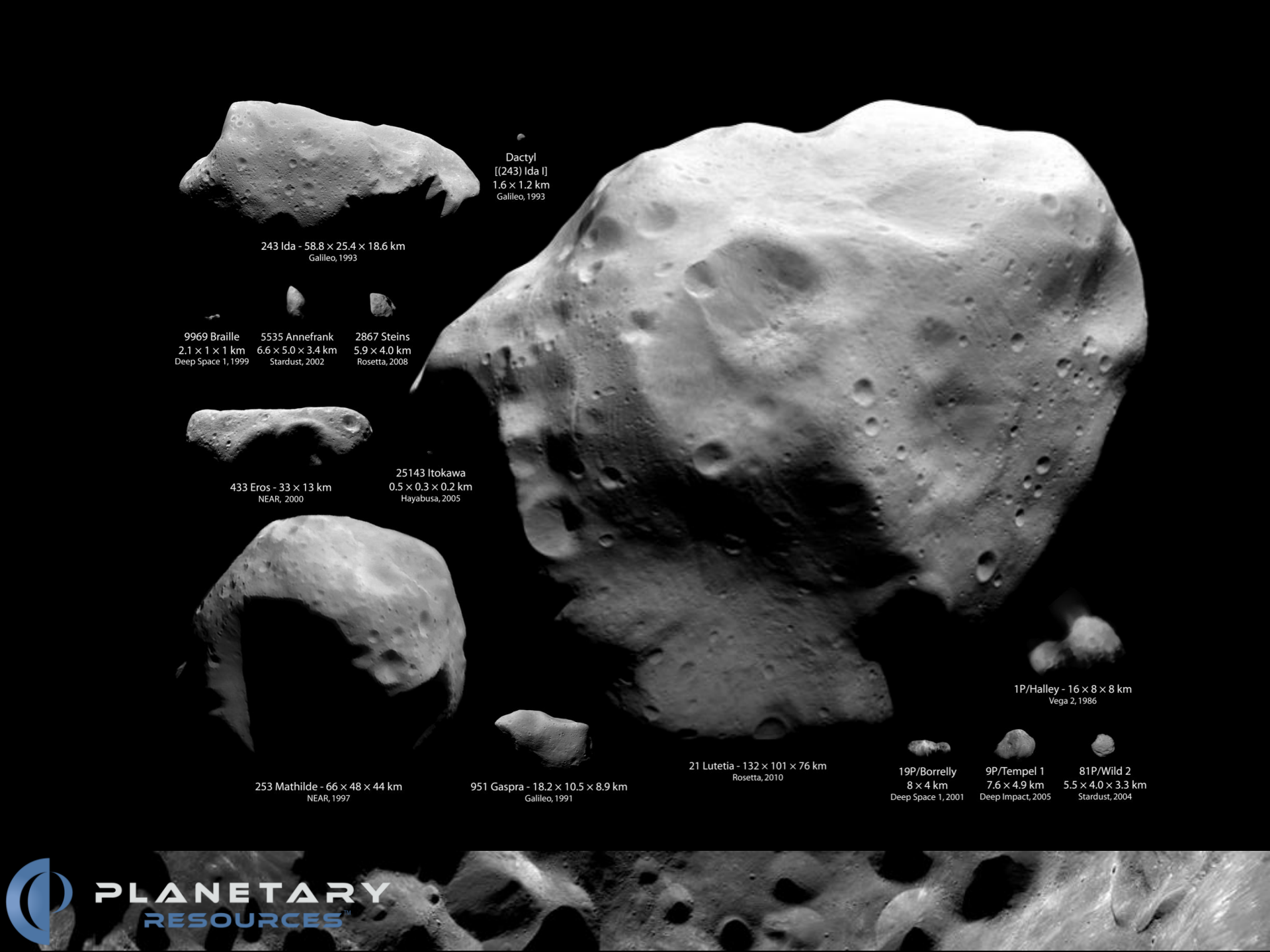
"The commercialization of space began with communications satellites and is developing for human spaceflight. The next logical step is to begin the innovative development of resources from space. I'm proud to be part of this effort."

Charles Simonyi

"I see the same potential in Planetary Resources as I did in the early days of Google. Some might look at asteroid mining and ask `*What if it fails?*' *I like to consider the possibility of `What if it succeeds!*'"

K. Ram Shriram

PLANETARY RESOURCES™


Dactyl
[(243) Ida I]
1.6 × 1.2 km
Galileo, 1993
243 Ida - 58.8 × 25.4 × 18.6 km
Galileo, 1993
9969 Braille
2.1 × 1 × 1 km
Deep Space 1, 1999
5535 Annefrank
6.6 × 5.0 × 3.4 km
Stardust, 2002
2867 Steins
5.9 × 4.0 km
Rosetta, 2008
433 Eros - 33 × 13 km
NEAR, 2000
25143 Itokawa
0.5 × 0.3 × 0.2 km
Hayabusa, 2005
1P/Halley - 16 × 8 × 8 km
Vega 2, 1986
253 Mathilde - 66 × 48 × 44 km
NEAR, 1997
951 Gaspra - 18.2 × 10.5 × 8.9 km
Galileo, 1991
21 Lutetia - 132 × 101 × 76 km
Rosetta, 2010
19P/Borrelly
8 × 4 km
Deep Space 1, 2001
9P/Tempel 1
7.6 × 4.9 km
Deep Impact, 2005
81P/Wild 2
5.5 × 4.0 × 3.3 km
Stardust, 2004
PLANETARY
RESOURCES™

PLANETARY RESOURCES™

Rich in Valuable Resources

hydrogen 1 **H** 1.0079	oxygen 8 **O** 15.999	carbon 6 **C** 12.011
iron 26 **Fe** 55.845	nickel 28 **Ni** 58.693	cobalt 27 **Co** 58.993

Asteroids contain concentrations of Platinum Group Metals many times greater than Earth's most productive mines

platinum 78 **Pt** 195.08	palladium 46 **Pd** 106.42	rhodium 45 **Rh** 102.91	iridium 77 **Ir** 192.22	ruthenium 44 **Ru** 101.07	osmium 76 **Os** 190.23

Present and Future Asteroid Value

✓ Science Data - $100s of Millions per year

More than $1B spent by governments in past decade on asteroid missions, proving concepts and reducing risk

✓ Material Resources - $100s of Billions per year

Thriving space economy fueled by space resources increases the GDP of the planet

✓ Survival of the Species - Priceless!

Capability developed for asteroid prospecting and mining supports mitigation of potentially hazardous asteroids

The Roadmap

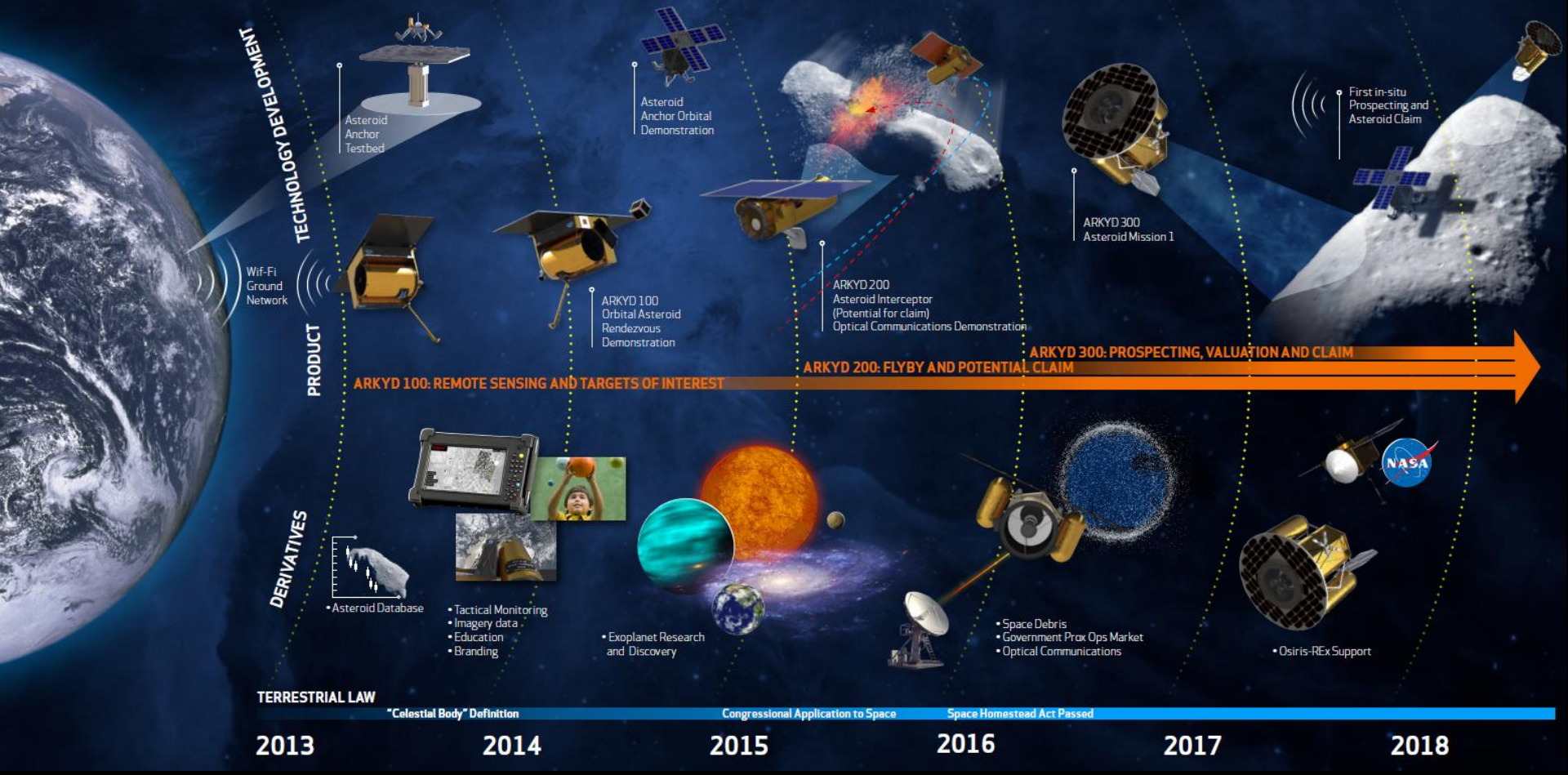
- Phase I: Identify, Prospect and Claim
- Phase II: Develop infrastructure and fuel depots
- Phase III: Mine and deliver PGM metals

PLANETARY RESOURCES™

TECHNOLOGY ROADMAP

PHASE ONE

TARGETING, PROSPECTING AND CLAIM



PLANETARY RESOURCES™

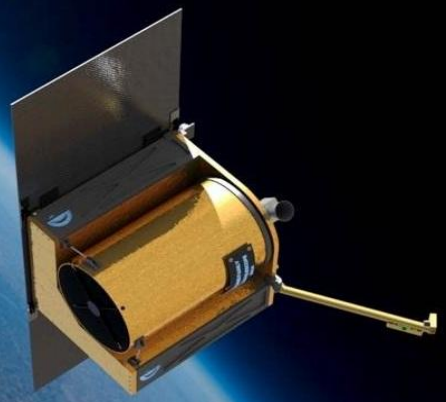
PLANETARY RESOURCES™

VISION
FOR THE FUTURE

PLANETARY RESOURCES™


PHASE TWO
FUEL & INFRASTRUCTURE DEVELOPMENT
VOLATILE PROCESSING AND POINT-OF-NEED DELIVERY
MARS
MOON
LOW EARTH ORBIT
2.5 km/sec
0.7 km/s
9.7 km/sec
3.4 km/sec
<1 km/sec
TRANSPORTATION PREPARATION
Delivery
Excavation Demonstration
In-Situ Processing Test Bed
Scalable Acquisition
Commercial Fuel Production
CARBONACEOUS ASTEROID
L2: The Crossroads of Space
PRODUCTION STAGE PRODUCTS
ADVANCED PRODUCTS
• H_2/O_2 Rocket Fuel
• Potable H_2O
• Other Volatiles
• Platinum Group Metals
• Bulk commodities
R&D STAGE DERIVATIVE PRODUCTS
BASIC PRODUCTS
• Radiation Shielding
• Steam Propulsion
• Solar Tugs
• Working fluids
DERIVATIVES (GOVERNMENT)
• NASA Mission Support
• Proprietary Data Sales
• Proximity Operation Tech
DERIVATIVES (COMMERCIAL)
• Mining R&D
• Autonomous Robotics
• Entertainment & Branding
Commercial Metal Production
In-Situ Processing Test Bed
Scalable Acquisition
Excavation Demonstration
METALLIC ASTEROID
PLANETARY RESOURCES
TECHNOLOGY ROADMAP
PHASE THREE
METALS
FUEL-ENABLED INFRASTRUCTURE DEVELOPMENT
METALLIC PROCESSING AND DELIVERY
PLANETARY RESOURCES

Unique Strategies & Approach



- Mass production of Arkyd Spacecraft (100's)
- In-house spacecraft integration & production line
- Leveraging exponentially growing technologies to build smaller, cheaper and more capable spacecraft
- Achieve redundancy and risk reduction through multiple spacecraft per mission (distributed operations – similar to distributed computing).
- Fly frequently to allow iteration in approaches

Incorporate recent, untapped commercial innovation into space applications

Next Action - what can I do?

Web	www.planetaryresources.com
Community Email List	eepurl.com/k_g81
Google+	gplus.to/PlanetaryResources
Twitter	@PlanetaryRsrcs
Facebook	facebook.com/PlanetaryResourcesInc
YouTube	youtube.com/user/PlanetaryResources

Watch for announcement of opportunities to participate soon!

PLANETARY RESOURCES™

We’re changing the way the world thinks about natural resources

Observation. Tactical Monitoring. Galaxy Astronomy. Exoplanets. Education.

TACTICAL EVENT MONITORING

PLANETARY RESOURCES

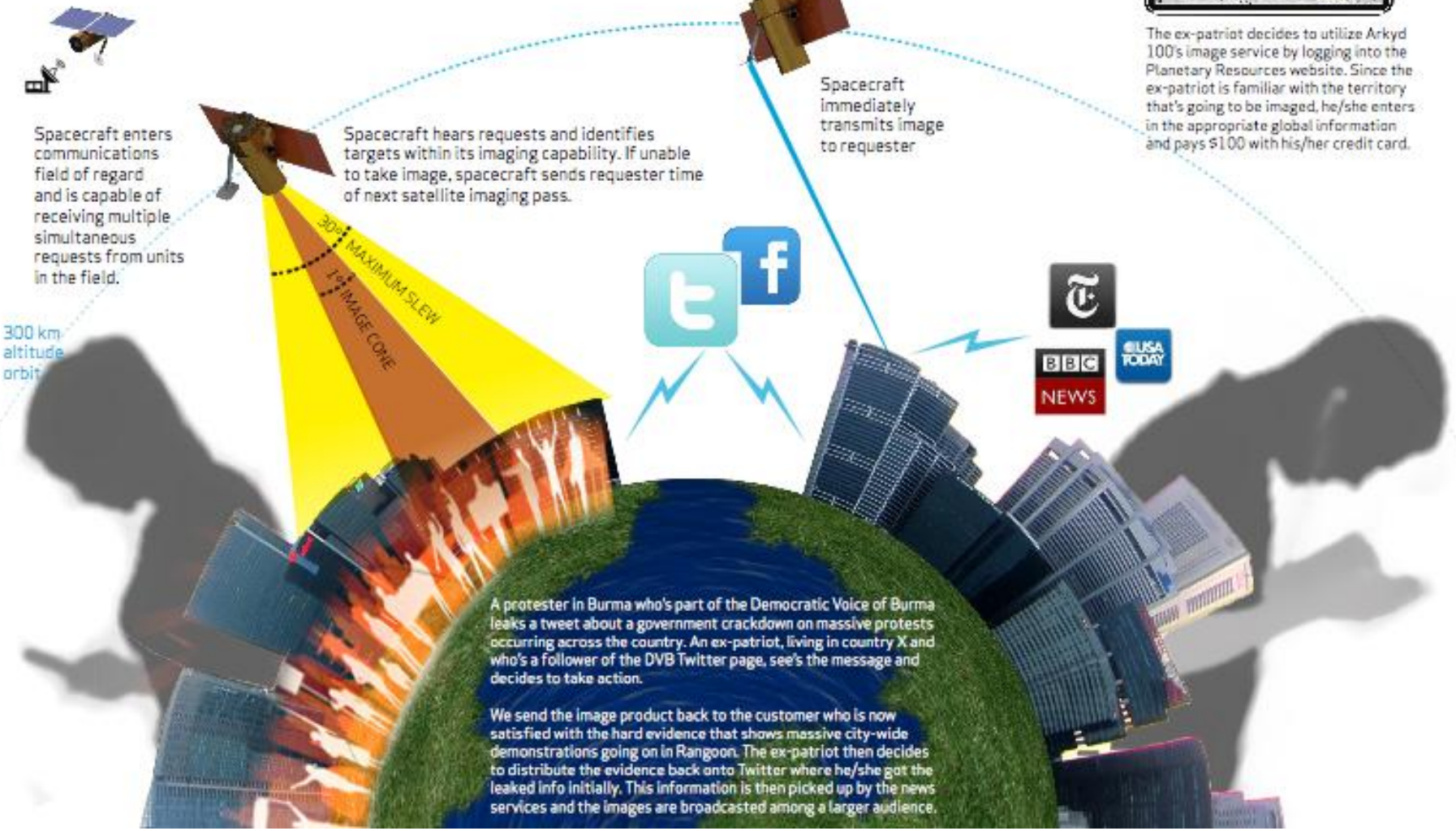
Observe current events as they unfold.

Spacecraft enters communications field of regard and is capable of receiving multiple simultaneous requests from units in the field.

Spacecraft hears requests and identifies targets within its imaging capability. If unable to take image, spacecraft sends requester time of next satellite imaging pass.

Spacecraft immediately transmits image to requester

The ex-patriot decides to utilize Arkyd 100's image service by logging into the Planetary Resources website. Since the ex-patriot is familiar with the territory that's going to be imaged, he/she enters in the appropriate global information and pays $100 with his/her credit card.



A protester in Burma who's part of the Democratic Voice of Burma leaks a tweet about a government crackdown on massive protests occurring across the country. An ex-patriot, living in country X and who's a follower of the DVB Twitter page, see's the message and decides to take action.

We send the image product back to the customer who is now satisfied with the hard evidence that shows massive city-wide demonstrations going on in Rangoon. The ex-patriot then decides to distribute the evidence back onto Twitter where he/she got the leaked info initially. This information is then picked up by the news services and the images are broadcasted among a larger audience.

Low Brightness Galaxy Astronomy

Observation. Tactical Monitoring. Galaxy Astronomy. Exoplanets. Education.

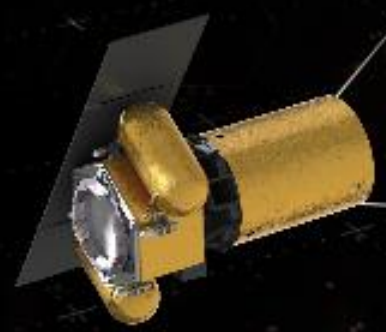
PLANETARY RESOURCES™

EXOPLANETS

PLANETARY RESOURCES

Discovering new planets is within your reach with the Arkyd 100 Series Space Telescope.

Of the estimated 300 billion planets in the Milky Way galaxy only ~800 have been discovered. Many of these are in a habitable zone and could hold life. Till recently only two space telescopes, operated by large research institutions, were dedicated to exoplanet discovery. The Arkyd 100 puts Exoplanet discovery within anyone's grasp. PRI's revolutionary space telescope is available for anyone who wishes to do astronomy research. Using a tablet or PC you select your targets and review the astronomical results to find exoplanets.



$$N = R^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

N = The number of civilizations in The Milky Way Galaxy whose electromagnetic emissions are detectable.

R* = The rate of formation of stars suitable for the development of intelligent life.

f_p = The fraction of those stars with planetary systems.

n_e = The number of planets, per solar system, with an environment suitable for life.

f_l = The fraction of suitable planets on which life actually appears.

f_i = The fraction of life bearing planets on which intelligent life emerges.

f_c = The fraction of civilizations that develop a technology that releases detectable signs of their existence into space.

L = The length of time such civilizations release detectable signals into space.

Methods to detect a planet

10,000,000,000,000,000,000,000 km away.

DOPPLER SHIFT

TRANSIT METHOD

GRAVITATIONAL MICROLENSING

DIRECT IMAGING

Arkyd 100 – An Educators Tool

Objective: Engage students in a multi-disciplinary course
Engages students in science, math, humanities, and activism through the implementation of a space mission to solve a real world problem - **using Arkyd 100 as their tool**

Phase I: Space Primer and Problem Statement
- Students are challenged to solve a real world geopolitical problem
- Students learn about satellite design and operation, lifecycle of a spacecraft and mission design
- Teams are given **up to 30 photos from anywhere** on Earth to complete their objectives

Phase II: Choose Mission and Find Partners
•Students choose and define a geopolitical "mission" (hunting for illegal whaling fleet, deforestation, etc) - **they are now the principal investigator**
•Divide into groups, perform background research, establish mission objectives

Phase III: Mission Planning
- Students identify specific targets of interest (Southern Ocean / Japanese ports)
- Teams access **the PRI mission planning toolset** to identify available spacecraft orbital details, available time periods for their observations, and the expected weather conditions
- Students formally request observation time from PRI and receive approval

Phase IV: Spacecraft Operations and Data Capture
•Requested images are acquired by the Arkyd 100
•Students participate directly in spacecraft operations with PRI personnel
•Data is downlinked from the spacecraft to PRI operations, **or to the school's own ground station**, within hours of acquisition and transmitted directly to student team
•Students analyze the imagery data to determine success / failure of mission objectives, and plan next observation(s)

Phase V: Analysis and Reporting
- Students complete all requested operations on Arkyd 100 and compile.
- Students participate directly in spacecraft operations with PRI personnel
- Students report out on their findings, issues, **and lessons learned**
- Teams share their findings **with other Arkyd 100 principal investigators** from around the world

Observation. Tactical Monitoring. Galaxy Astronomy. Exoplanets. Education.

PLANETARY RESOURCES™