



National Council of Space Grant Directors - 2006 Spring Meeting

Centennial Challenges



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Supporting Centennial Challenges
Advanced Capabilities Division
Exploration Systems Mission Directorate
NASA Headquarters
March 17, 2006*

Centennial Challenges Introduction



◆ What Is Centennial Challenges?

- Prize competitions supporting space exploration and NASA priorities
- Builds on Longitude Prize, early aviation prizes, X PRIZE, and DARPA Grand Challenge

◆ Program Goals

- Stimulate innovation in ways standard federal procurements cannot
- Enrich NASA research by reaching new communities
- Help address traditional technology development obstacles
- Achieve returns that outweigh program investment
- Motivate, inspire and educate the public

◆ Structure of Challenges

- Flagship
- Keystone
- Alliance
- Quest



CC Today: 8 Alliance Challenge Competitions



◆ \$1.9M in Prize Purses

- \$200K – High Strength-to-Weight Materials
- \$200K – Wireless Power Transmission
- \$250K – Advanced Astronaut Glove
- \$250K – Lunar Regolith Excavation
- \$250K – Moon Regolith Oxygen Extraction
- \$250K – Telerobotic Construction
- \$250K – Personal Air Vehicle
- \$250K – Planetary Unmanned Aerial Vehicle

◆ Prizes Have “PR” Built-In



FIRST COMPETITION IN 2005

- Wireless Power (\$50K)
- High S/W Materials (\$50K)
- 11 teams spent \$200K
- Small companies, university students, and hobbyists
- Fresnel lenses, multi-junction cells, Sterling engines
- No winners, but...
 - 1st beam-powered climbers
 - Near-winners on materials
- 12.5M TV viewers
 - \$570K equivalent in advertising
- Next year's teams came across country to check out the competition

List of Current Allied Organizations



Dr. Brien
Seeley



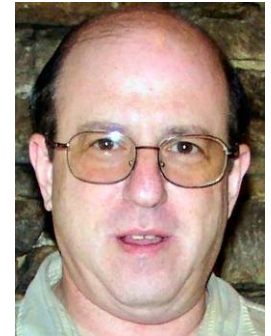
Ms. Janice
Dunn



Mr. Edward
Ellegood



Ms. Meekk
Shelef



Dr. Alan
Hayes



Mr. Stephen
Williams



Mr. Matt
Everingham



Mr. Tim
Bailey



Mr. Ben
Shelef



Dr. Sigmund
Gorsky

List of Current Allied Organizations



Challenge	Allied Organization	Contact
Regolith Excavation	California Space Education and Workforce Institute www.californiaspaceauthority.org	Janice Dunn janice.dunn@californiaspaceauthority.org
Planetary Unmanned Aerial Vehicle		
2005-06 Tether	The Spaceward Foundation www.spaceward.org	Ben Shelef ben@spaceward.org
2005-06 Beam Power		
2007-08 Telerobotic Construction		
Personal Air Vehicle	Comparative Aircraft Flight Efficiency Foundation www.cafefoundation.org	Dr. Brien Seeley cafe400@sonic.net
MoonROx	Florida Space Research Institute www.fsri.org	Edward Ellegood eellegood@fsri.org
Astronaut Glove	Spaceflight America / Volanz Aerospace Inc. www.spaceflightamerica.org	Dr. Alan Hayes ahayes@spaceflightamerica.org



CC To Come: 8 New Competitions

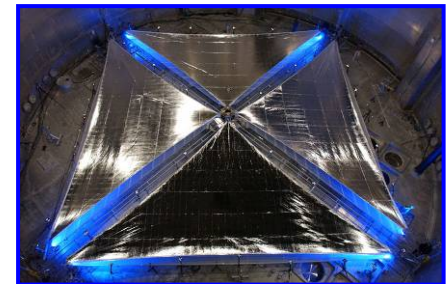
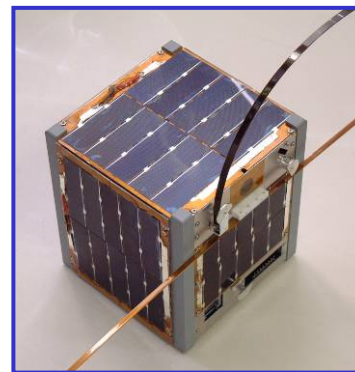
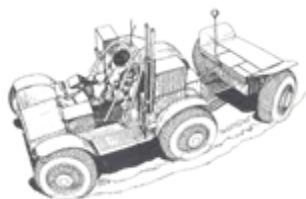
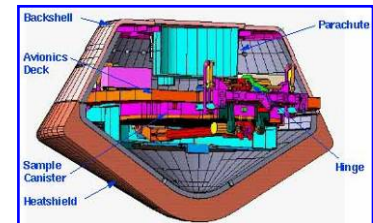


◆ Flagship Challenges

- \$5M – Fuel Depot Demonstration
- \$2M – Lunar Lander Analog
- \$2M – Micro Reentry Vehicle
- \$5M – Station-Keeping Solar Sail

◆ Keystone Challenges

- \$1M – Human Lunar All-Terrain Vehicle
- \$500K – Low-Cost Space Pressure Suit
- \$500K – Non-Toxic RCS Engine
- \$500K – Lunar Night Power Source



Allied Organizations On The Horizon



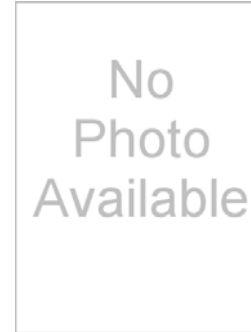
Mr. George Whitesides



Dr. Pat Hynes



Dr. Bruce Betts



Ms. Krysta Paradis



Dr. Peter Diamandis



Mr. Brett Silcox



Mr. Mike Heney



Mr. Will Pomerantz



◆ Become an Allied Organization

- NASA guarantees payment of purse payment.
- AO agrees to administer and execute a competition at no cost to the government.

◆ Support a Competing Team

- Must address restrictions on federal government funding.

◆ Support an Existing Allied Organization

- Event or year-round opportunities.
- Internships, scholarships, volunteers.

◆ Provide Input, Comments to CC

- Send new competition ideas and rules to “ccideas@nasa.gov”.
- Go to “www.centennialchallenges.nasa.gov” and click on “Submit Your Ideas”.
- Send an email to “kdavidian@nasa.gov”.



The End

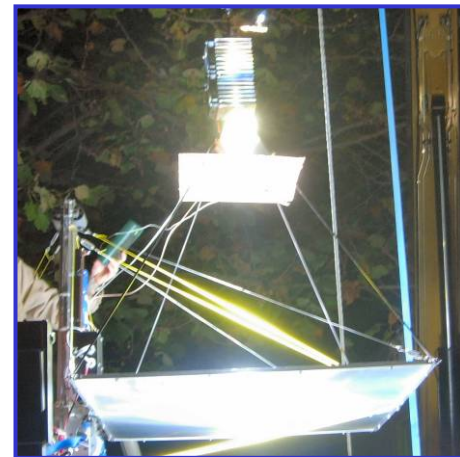
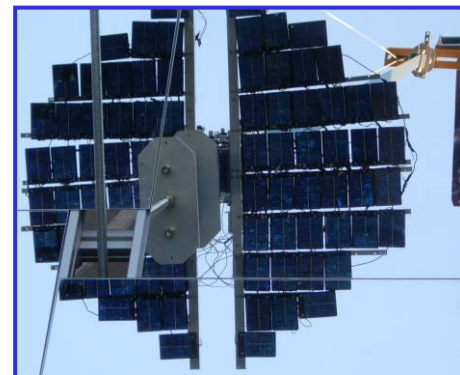
Any Questions?

Summary

- ◆ Teams must deliver climber, receiver, and transmitter
- ◆ Mass of climber and receiver constrained to 25 kilograms
- ◆ Drive solutions with high power densities
- ◆ Allowed 3 attempts to climb 50 meter cable in 3 minutes
- ◆ Most mass lifted wins
- ◆ Teams must deliver climber, receiver, and transmitter
- ◆ No teams won the 2005 purse of \$50,000
- ◆ 2006 Purse
 - 1st place: \$125,000
 - 2nd place: \$50,000
 - 3rd place: \$25,000

Important Capabilities For

- ◆ Surface- or space-based, point-to-point power transmission delivery for robotic or human expeditions
- ◆ Supports far-term space infrastructure concepts

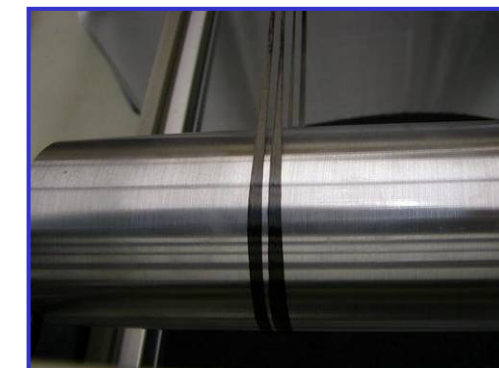
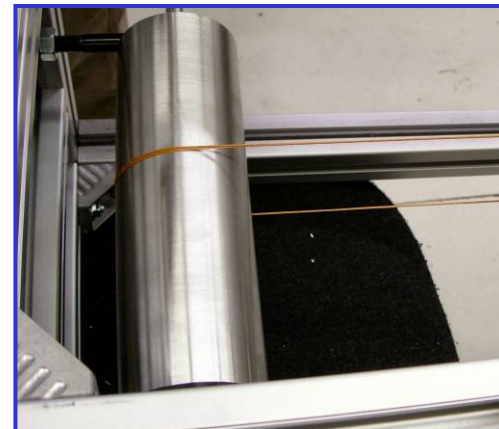


Summary

- ◆ Teams develop and deliver tethers made from high strength-to-weight materials
- ◆ Each team's tether is stretched in tension rig in head-to-head competition against another team's tether
- ◆ Team with the tether that does not break advances to the next round of the bracketed competition
- ◆ Winner of all brackets must then beat the strength of the "house" tether (strongest pre-existing tether) by 50 percent to win the Challenge
- ◆ No teams won the 2005 purse of \$50,000
- ◆ 2006 Purse
 - 1st place: \$125,000
 - 2nd place: \$50,000
 - 3rd place: \$25,000

Important Capabilities For

- ◆ High strength-to-weight materials
- ◆ Application to wide variety of structural purposes

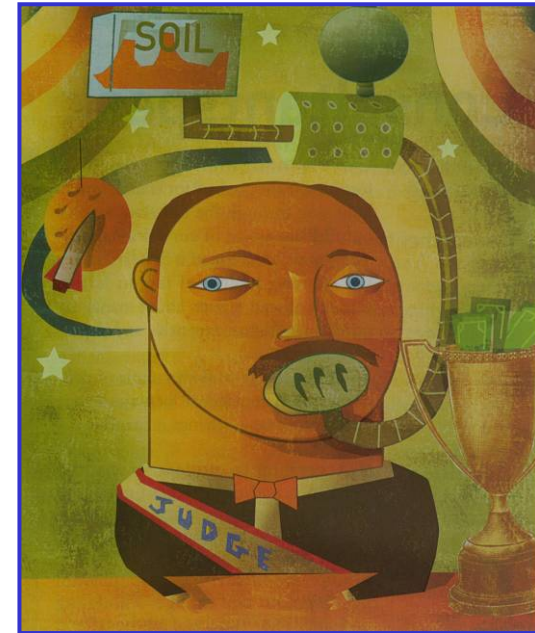


Summary

- ◆ First team to demonstrate an autonomous system that extracts 5 kilograms of oxygen in under 8 hours from soil (regolith) simulant wins
- ◆ Exhaust gas must be $< 1\%$ H_2 and breathable
- ◆ Teams must deliver MoonROx Hardware
 - mass limited to 25 kg
 - power limited to 3kW and/or solar flux
 - penalties for consumables used in processes
- ◆ FSRI to provide
 - regolith simulant (JSC-1) for prize attempt
 - O_2 monitoring and storage equipment
- ◆ \$250,000 purse expires June 1, 2008

Important Capabilities For

- ◆ In-Situ Resource Utilization
- ◆ Oxygen extraction from lunar regolith
- ◆ Vital technology for long-duration, human exploration



Summary

- ◆ Teams must provide
 - Gloves (bladder-restraint only) to be tested in space suit pressurized conditions
 - Arm pieces (but not part of the competition)
 - All interfaces to competition event glove box
- ◆ Glove Minimum Design Requirements
 - Mass less than 400 grams
 - Finger range of motion between 45-75 degrees
 - Must pass pressurization tests
- ◆ Gloves must perform and get scored on three tests
 - Force measurements of finger and wrist joints – to find the glove that is easiest on hand fatigue
 - Dexterity and flexibility tasks/tests – to find the glove that is easiest to use
 - Hydrodynamic burst test - to find the glove that is the strongest
- ◆ Volanz to provide the competition event glove box



Important Capabilities For

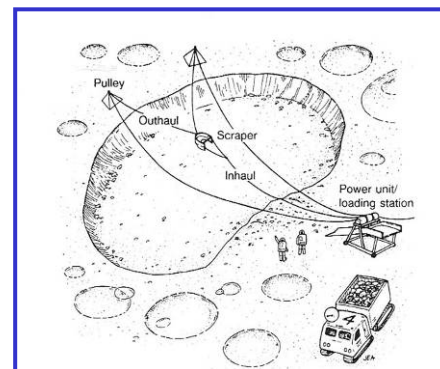
- ◆ Improved manual dexterity and sensitivity
- ◆ Decreased manual fatigue
- ◆ Lighter weight, stronger, more durable

Summary

- ◆ Team that autonomously excavates and delivers the most lunar soil simulant to a collection point within 30 minutes wins
 - Excavated mass must exceed 100kg
- ◆ Teams provide excavation hardware
 - Mass limited to <25 kg
 - Power limited to <30 W DC
 - Approximately sized for robotic mission demonstration
- ◆ CSA/CSEWI provides
 - 4m x 4m x 50cm “sandbox”
 - 16 metric tons of compacted JSC-1a

Important Capabilities For

- ◆ Lunar in-situ resource utilization
- ◆ Lunar radiation shielding
- ◆ Lunar site preparation



Summary

- ◆ Flight course contest to improve utility of small aircraft for public use with awards in five PAV areas:
 - PAV Prize (\$150K) – Best combination of door-to-door trip velocity, energy consumption, and passenger carrying performance
 - Community Noise Prize (\$25K) – Lowest noise from ground
 - Cabin Noise Prize (\$25K) – Lowest noise inside aircraft
 - Handling Prize (\$25K) – Best performance in static longitudinal stability, maneuvering stability, spiral stability, stall characteristics, and takeoff and landing characteristics
 - Ease-of-Use Prize (\$25K) – Awarded by judging panel



Important For

- ◆ Extending small aircraft to new users and applications
- ◆ Testing small-scale air system technologies with broader implications
- ◆ Leveraging and focusing experimental aircraft community

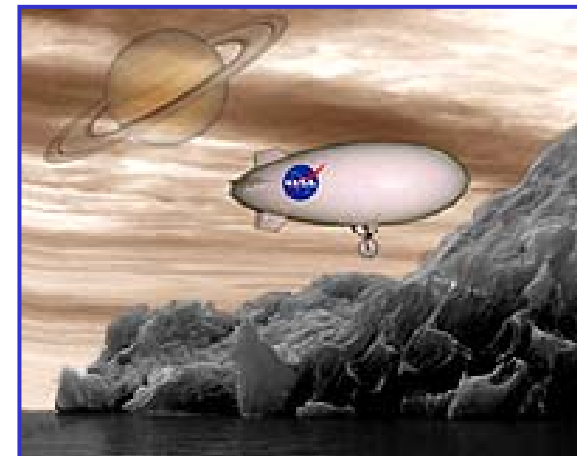
Summary

- ◆ Autonomous, lighter-than-air flight course with awards for quickest time and most accurate sampling
 - Course includes 30 meter ascents, 360-degree turns, and ground samplings
 - No GPS navigation allowed
- ◆ Teams provide autonomous, lighter-than-air vehicle
 - Mass limited to <5 kg
- ◆ CSA/CSEWI provides course
 - Enclosed or partially enclosed stadium



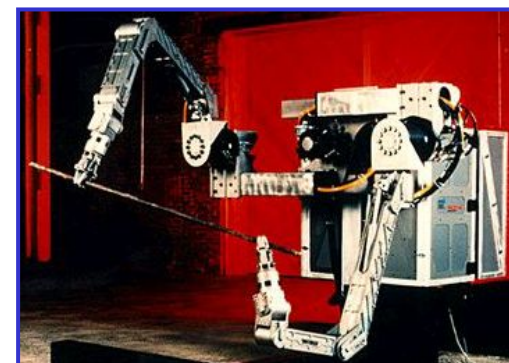
Important Capabilities For

- ◆ Mars, Titan, and Venus exploration
- ◆ Planetary surface access and sampling
- ◆ Autonomous, non-GPS navigation



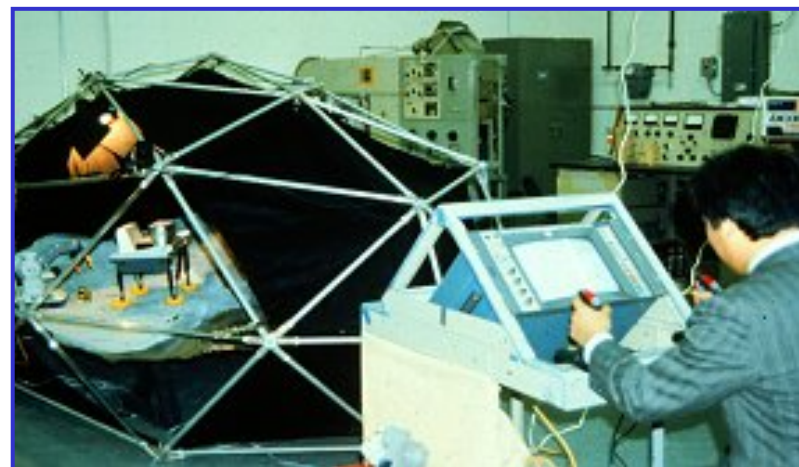
Summary

- ◆ Team that telerobotically constructs a simulated lunar structure (e.g., pipeline or habitat) from common materials in shortest time wins
- ◆ Teams provide construction hardware and human interface
 - Challenge complexity likely to require multiple robots
 - Level of autonomy up to teams
- ◆ Spaceward provides
 - Communications limited by time, bandwidth, latency
 - Common structure design and set of materials



Important Capabilities For

- ◆ Lunar site preparation
- ◆ Human-machine interaction
- ◆ Other space construction and operations



New Flagship Challenge

Fuel Depot Demonstration

Rationale

- ◆ Administrator comments made at the American Astronautical Society 52nd Annual Conference on 15 November 2005:
 - *“But if there were a fuel depot available on orbit, one capable of being replenished at any time, the Earth departure stage could after refueling carry significantly more payload to the Moon, maximizing the utility of the inherently expensive SDHLV for carrying high-value cargo.”*
 - *“But NASA’s architecture does not feature a fuel depot. Even if it could be afforded within the budget constraints which we will likely face – and it cannot – it is philosophically the wrong thing for the government to be doing... It is a highly valuable enhancement, but the mission is not hostage to its availability. It is exactly the type of enterprise which should be left to industry and to the marketplace.”*
 - *“If a commercial provider can supply fuel at a lower cost, both the government and the contractor will benefit. This is a non-trivial market, and it will only grow as we continue to fly.”*



Rules Summary

- ◆ To win the estimated \$5M prize, the Team shall:
 - Launch at least 20 kg of hydrogen and at least 120 kg of oxygen to LEO (an orbit greater than 200 km)
 - As separate elements or combined in a more complex molecule (e.g., water)
 - Maintain in orbit for 4 months, with the propellants stored as a liquid, (H_2 less than 20 K, O_2 less than 90 K) for at least 2 weeks at a measured pressure and total mass.



New Flagship Challenge

Lunar Lander Challenge



Rationale

- ◆ Demonstrate on Earth technically relevant rocket engines and landing systems for lunar landers and VTVL launchers:
 - Broaden industrial base for lunar transportation infrastructure
 - Accelerate development of commercial launch industry

Rules Summary

- ◆ To win the estimated \$1M first place prize or the estimated \$250K second place prize, the Team shall:
 - Launch a 100kg payload vertically
 - Maintain an altitude of 20-50m for 3 minutes (relevant lunar delta-V)
 - Translate at least 100m
 - Land vertically
 - Refuel and repeat within 2 hours

Signed Letter of Intent With X PRIZE Foundation

- ◆ Competition to take place at annual X PRIZE Cup events in NM
- ◆ Negotiating final Space Act Agreement with X PRIZE
 - X PRIZE negotiating with aerospace prime to cover administrative costs
- ◆ Announce at FAA Commercial Launch Symposium February 9-10
 - At least one emergent company will immediately enter



New Flagship Challenge

Micro Reentry Vehicle

Rationale

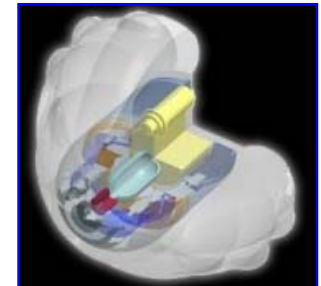
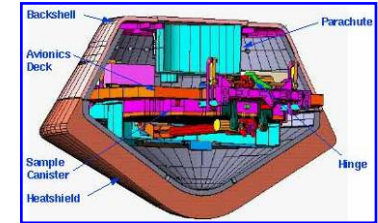
- ◆ Demonstrate a low-cost method for returning viable samples on-demand from orbit:
 - Routine ISS sample return despite constrained downmass
 - Free-flying research platforms in between vomit comets and ISS
 - Commercial biotech interest

Rules Summary

- ◆ To win the estimated \$2M prize, the Team shall:
 - Launch one dozen raw eggs into LEO (>200km)
 - Reenter the Earth's atmosphere and land within 4km of the team's pre-designated landing site
 - Protect the eggs from temperatures, vibrations, and accelerations resulting in cooking, scrambling, or cracking

Also Supports Spacecraft “Black Box” Data Applications

- ◆ Aerospace Corporation



New Flagship Challenge

Station-Keeping Solar Sail

Rationale

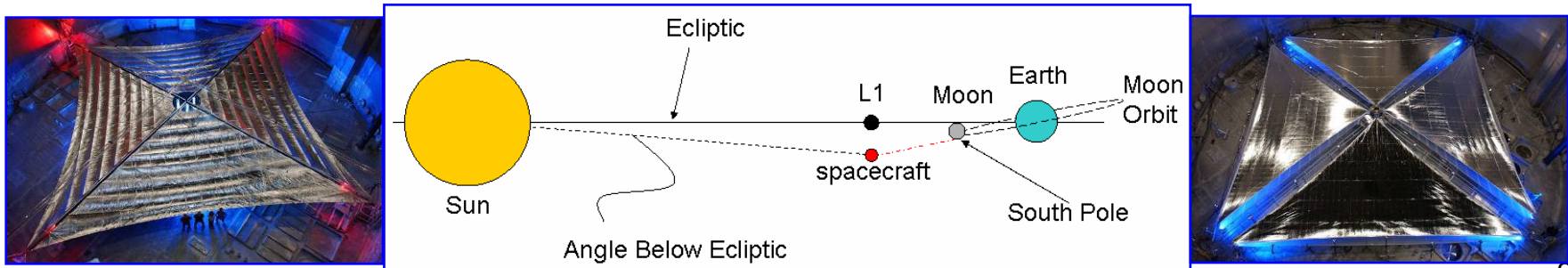
- ◆ Demonstrate the ability to enter and maintain orbit around an artificial Lagrange Point outside the ecliptic for long periods of time:
 - “Stare-down” capability to Moon’s poles for lunar communications and remote sensing (NASA)
 - “Stare-at” the Sun for solar weather forecasting (NOAA)
 - “Stare-down” capability to Earth’s poles for communications and remote sensing (NSF)
- ◆ Demonstrate in space broadly applicable solar sail propulsion

Rules Summary

- ◆ To win the estimated \$2.5M sail acceleration prize, the Team shall:
 - Demonstrate a sail acceleration of at least 0.05 mm/sec^2
 - Use the sail to establish a delta trajectory that passes thru a circle 1.3 million kilometers in diameter that is centered on and perpendicular to the Earth-Sun L1 point
- ◆ To win the estimated \$2.5M station-keeping prize, the Team shall:
 - Maintain position within 100,000 kilometers of a point at least 6 degrees off the Earth-Sun line for 90 consecutive days

Strong Interagency Interest

- ◆ NOAA to decide in March whether to budget ~\$50M for follow-on data service contracts
- ◆ NSF may also offer ~\$20M in follow-on Antarctic communications relay contracts



New Keystone Challenge

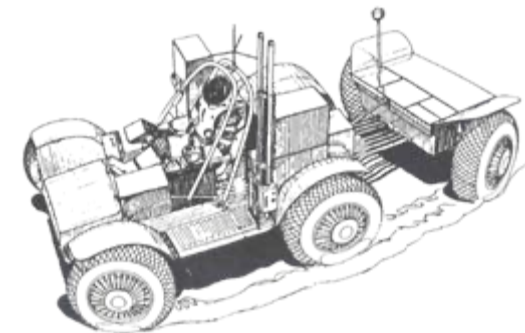
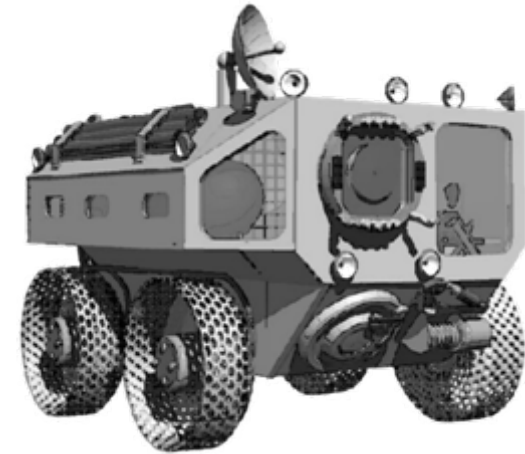
Human Lunar All-Terrain Vehicle

Rationale

- ◆ Use terrestrial capabilities to develop human lunar rover systems at low cost.

Summary

- ◆ The Vehicle hardware shall:
 - Weigh less than 300 kg (empty).
 - Carry 2 crew and 2 m³ of payload weighing 200 kg.
 - Stowed volume limit: 2.5 m³
 - Travel at a velocity of 10 km/h or more.
- ◆ To win the \$1M (est.) purse, the team shall:
 - Unstow and assemble their vehicle hardware in 10 minutes or less.
 - Negotiate 10 km on a test track (including boulders, craters, hair-pin turns, etc.) with a minimum average speed of 10 km/h.
 - Have the fastest overall time.



New Keystone Challenge

Low-Cost Space Pressure Suit

Rationale

- ◆ Broaden EVA industrial base
- ◆ Accelerate private human space flight

Summary

- ◆ First to Demonstrate competition, expires by 2010.
- ◆ Judges will confirm that the space pressure suit shall:
 - Be sizable for passengers of all sizes (from 5% American female to 95% American male).
 - Be comfortable and allow unrestricted mobility when unpressurized.
- ◆ Performance Requirements - To win the \$500,000 (est.) purse, the space pressure suit must:
 - Successfully demonstrate the ability to protect the wearer from a rapid (3 second) decompression.
 - Sell at least 10 suits in a competitive and open market.



New Keystone Challenge

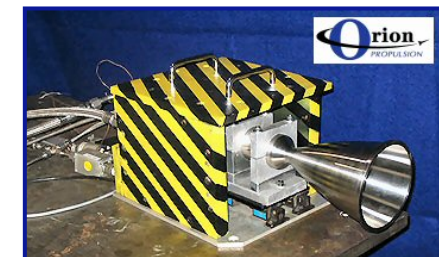
LOX/LCH4 Reaction Control Engine

Rationale

- ◆ Seed industry to maintain future ISRU architecture options

Summary

- ◆ First-to-Demonstrate competition, with 1st and 2nd place purses totaling \$300,000 (est.)
- ◆ To win the purse, the engine system shall:
 - Thrust: 100 pounds
 - Specific Impulse: >300 sec
 - Minimum Impulse Bit: <5 lb-sec
 - Demonstrated Life: Max burn 300 sec; 100x pulse cycles
 - Cryogenic Propellants
- ◆ Competition to take place at annual X PRIZE Cup events in NM
- ◆ Potential Competitors: Traditional & Start-Ups
 - P&W/Rocketdyne, Aerojet, XCOR, Orion Propulsion, Advent



New Keystone Challenge

Lunar Night Power Source

Rationale

- ◆ Use lunar night demands to push boundaries of power storage technology

Summary

- ◆ To win the \$500,000 (est.) purse, the power system shall:
 - Be no larger than 0.027 m³ (e.g., a 30 cm cube).
 - Pass a vacuum test without excessive off-gassing or leakage.
 - Recharge fully within one Lunar Day (approx. 350 hours).
 - Provide 600 watt-hours/24 hours at 24-36 Volts DC for a typical lunar rover load profile.
 - Perform in a relevant thermal environment (-35°C to -4°C) for one Lunar Night (approx. 350 hours).

