National Aeronautics and Space Administration


# Leveraging Early Commercial Services for Lunar Vision

## NASA 2009 Lunar Science Forum

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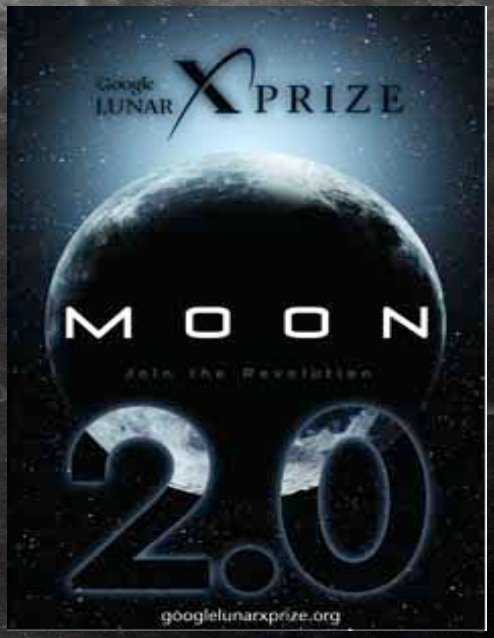
July 2009

# Utilization of the Moon for NASA's Vision

- **ON the Moon**
  - Exploration and technology development/demonstration to reduce risk/cost avoidance for systems supporting the Altair, EVA and LSS
- **FROM the Moon**
  - Observations from the moon toward earth for earth/climate "whole-disc" assessments
  - Observations from the moon away from earth for far-side astronomy
    - Radio astronomy
    - Astrophysics
    - Heliophysics
- **ABOUT the Moon**
  - Support planetary science research leading to increased understanding on the Moon
    - Its process, evolution, chronological dating
      - Tied to NRC report

# Leveraging early commercial services for Lunar

1. Commercial payload deliver and lunar data supporting architecture
   - beginning as early as 2011
2. Commercial lunar comm and nav as early as 2015
3. Commercially-provided capability for landing site prep
   - Site surveys
   - Grading/berms
4. Commercial lunar commodities:
   - Lunar oxygen for life support, water production, propellant
     - MINER
   - Power/energy



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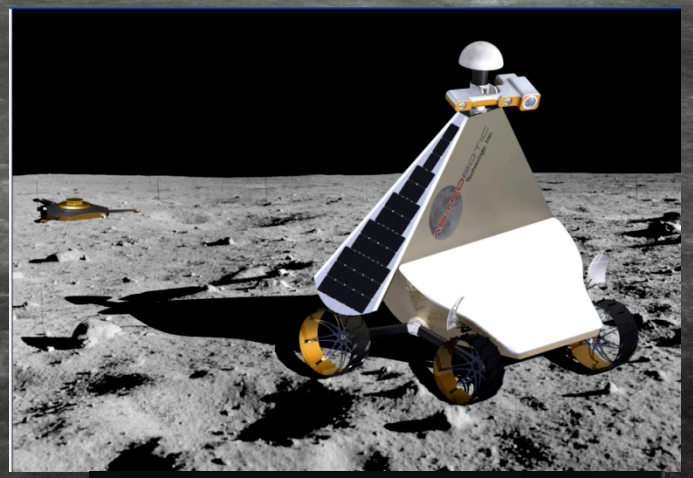
# Lunar Commercial Payload Delivery

## LunEx

*"I have also long believed it should be a balanced program that includes both robotics and human involvement, and our focus will be on the human space flight aspect and that part of the robotics program that links directly to human space flight."*

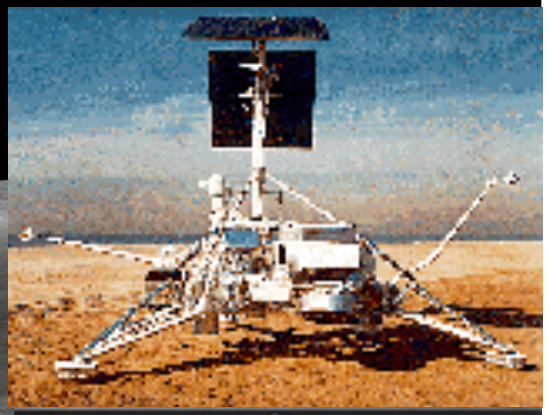
Norm Augustine on Human Spaceflight Review 5/8/09



www.nasa.gov

# SURVEYOR – Goals and Objectives

- **Goal** – achieve soft landings on the Moon by automated spacecraft capable of transmitting engineering and scientific measurements from the lunar surface.
- **Objectives:**
  - Develop technology for soft-landing on Moon
  - Survey Apollo landing sites
  - Provide data for the Apollo lunar lander design with conditions encountered on the Moon
  - Add to scientific knowledge of the Moon.

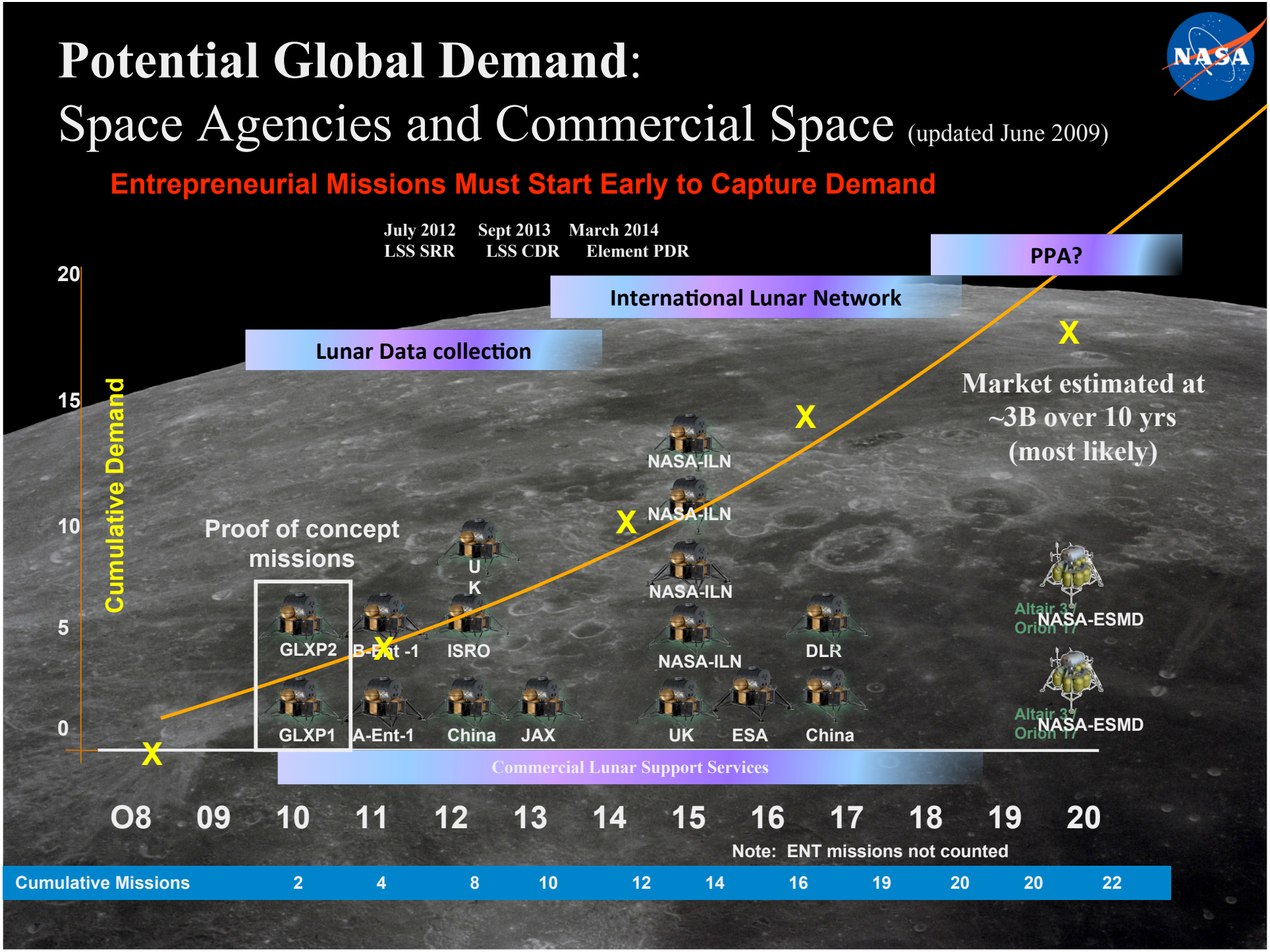


# Lunar Commercial Payload Delivery - Goal…..

- Obtain lunar data for NASA through commercial services
  - Utilize emerging commercial capability to land payloads on the Moon
    - Includes lunar data purchase and/or NASA lunar instrument delivery
  - Cost to NASA that is less than a dedicated NASA robotic mission
  - Operations could begin in 2011 timeframe

# Potential Global Demand:
## Space Agencies and Commercial Space (updated June 2009)

**Entrepreneurial Missions Must Start Early to Capture Demand**



# (Lunar-COTS)

LunEx

- Goal: "buy the ride" or "buy the data"
- Small (<$100M), fully commercial end-to-end capability
  - Small-class launch vehicle/lander - few kg up to 100+ kg payload
  - Medium-class launch/lander – 300-400kg payload
- Frequent, multiple flights
- Commercially-leveraged: Open Competition for lunar transportation services
- Fixed price service
- NASA Class-D type mission portfolio
  - Similar to LCROSS
- Approach: Industry provide the "Fed-Ex" to the surface

# NASA Lunar Commercial Services : "what's new over the last year?"

## Commercial Lunar Payload Delivery/Data-Buy

- Goal: "buy the ride" or "buy the data" using commercially-demonstrated capability …As soon as early 2011
- Service pool from: GLXP, Lockheed "Lunar Express", ATK LLL, others
- NASA collection of lunar data 'desirement' list of "demand": ESMD/SOMD
- Assessing NASA options for advanced purchase commitments and prizes
- Continued discussion w/ NASA Lunar Science Inst. on data acquisition

## Lunar Commodities

- Commercially-provided lunar oxygen to support human lunar return
  - Life support, water production, propellant
- Performed risk-adjusted cost analysis (RANPC) for Commercial Lunar $O_2$
- ISRU has potential to save >$1B/yr … >5x cost trade
- Seeking funding for early flight test demo of $O_2$ extraction (MINER)

# MINER Concept Overview

**GOAL** – provide design and operational data and address uncertainties associated with lunar regolith and environment for lunar $O_2$ production with regolith using industry partnership

**Approach**

- Lunar ISRU $O_2$ flight experiment: design and performance scalable to Outpost production method
- Low weight/low power/low cost
  - <50kg experiment flight package
  - Low cost, commercially leveraged
- Operate for as long as possible with multiple cycles
- Incorporate science instruments for resource characterization, performance evaluation and lunar science
- Public engagement

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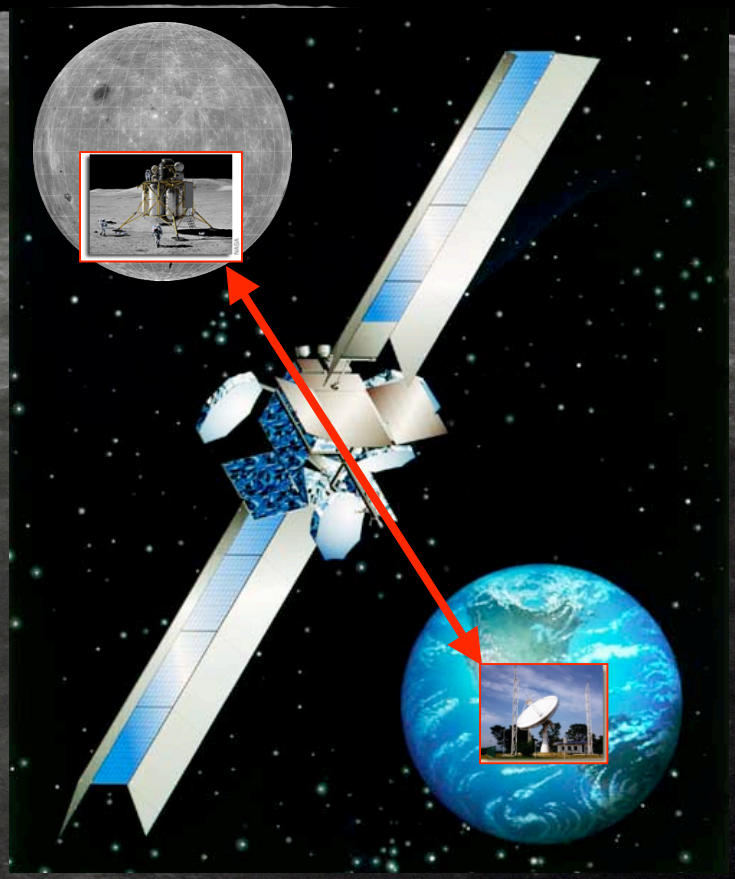
# Strategies for Achieving Commercial Lunar Communications & Navigation (C&N):
## Concepts for Industry Comment

Collaboration between
Exploration Systems Mission Directorate
Commercial Crew & Cargo Program Office (C3PO)
*Rob Kelso, Lead*
*Jon Michael Smith*

And

Space Operations Mission Directorate
Space Communications and Navigation (SCaN) Program Office
*Jim Schier*





DRAFT for RFI Package

# NASA Lunar Commercial Services : "what's new over the last year?"

## Commercial Lunar Communications/Navigation

- Completed strategic study on commercial lunar comm/nav
- Lunar C&N is a good candidate for commercial service provider(s)
- The aggregate C&N portfolio (demand) will grow over the decades
  - Science, then Science + Exploration
- Early commercial C&N could demonstrate reliability & build confidence
- Commercial entity provides/manages infrastructure
  - Market based on total aggregate bandwidth
    - NASA + International + Commercial + Defense
  - Determine NASA leveraged investment/contribution
  - Contracts-in-waiting for bandwidth ($/kbps)

# 3 Phases of Commercial Lunar C&N Strategy

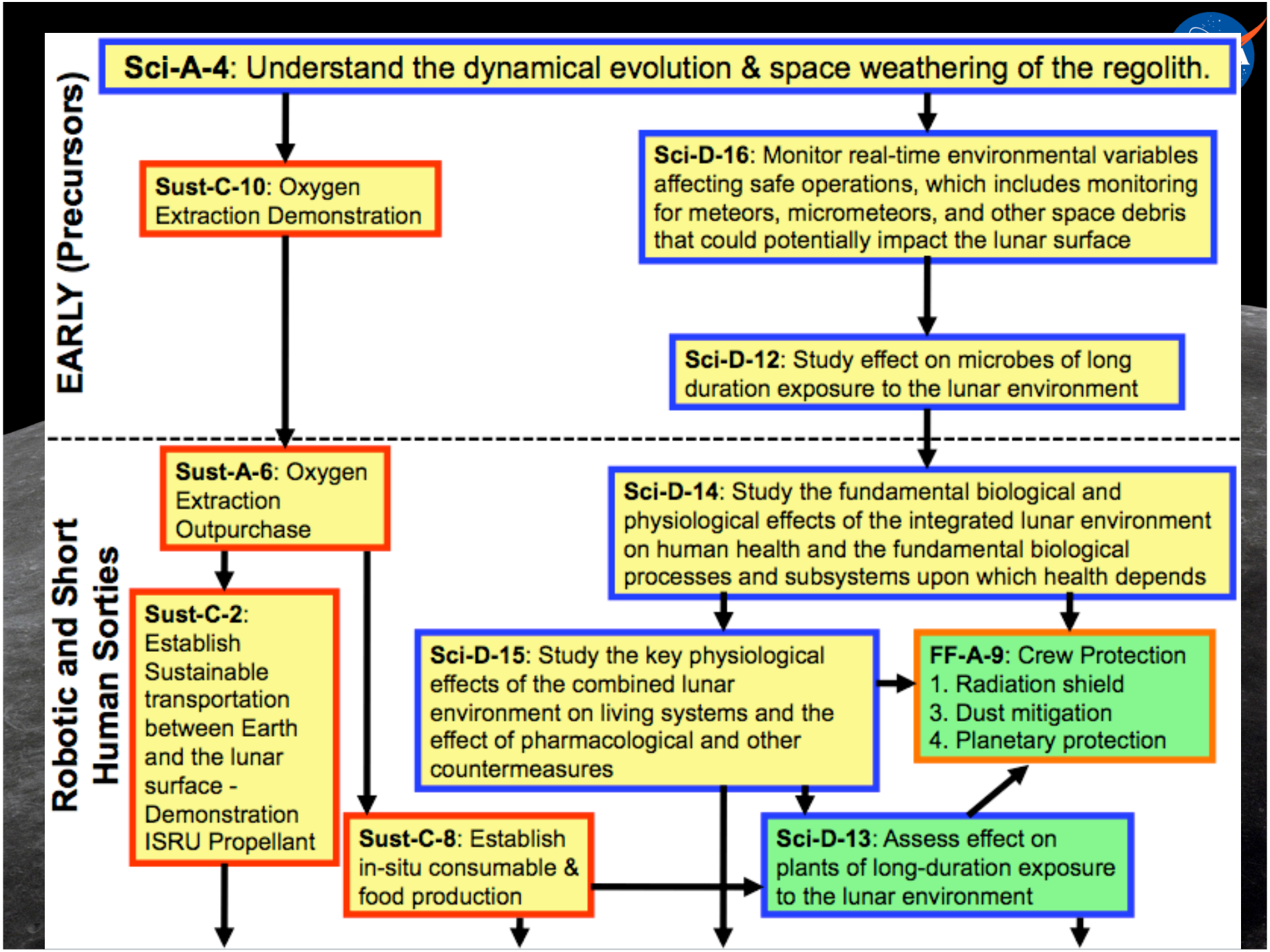
- S-1 (2010-2013)
  - Ops: Early Missions = DTE Comm
  - Testing & Development
    - Subsystems DDT&E
    - Test/Dev S-2/Demos
    - Early Commercial Backbone
    - Key is synergy between NASA, Commercial and DOD test programs
- S-2 (2013-2018)
  - Ops: ILN + Intl Science missions + Farside moon missions
    - Products by Commercial C&N Network Backbone
    - No NASA Network Backbone
- S-3 (2018-2020+)
  - Ops: Altair and Outpost mxs
    - Users: Same as S-2 + Outpost science/user data
    - Manned ops for outpost/Altair (assured comm) by NASA Backbone

# NASA Lunar Commercial Services : "what's new over the last year?"

- **Commercially-provided capability for landing site prep**
  - Landing site reconnaissance and surveillance
  - Landing site stabilization techniques
  - Berming, etc




# Backup


EARLY (Precursors)
Robotic and Short Human Sorties
Sci-A-4: Understand the dynamical evolution & space weathering of the regolith.
Sust-C-10: Oxygen Extraction Demonstration
Sci-D-16: Monitor real-time environmental variables affecting safe operations, which includes monitoring for meteors, micrometeors, and other space debris that could potentially impact the lunar surface
Sci-D-12: Study effect on microbes of long duration exposure to the lunar environment
Sust-A-6: Oxygen Extraction Outpurchase
Sci-D-14: Study the fundamental biological and physiological effects of the integrated lunar environment on human health and the fundamental biological processes and subsystems upon which health depends
Sust-C-2: Establish Sustainable transportation between Earth and the lunar surface - Demonstration ISRU Propellant
Sci-D-15: Study the key physiological effects of the combined lunar environment on living systems and the effect of pharmacological and other countermeasures
FF-A-9: Crew Protection
1. Radiation shield
3. Dust mitigation
4. Planetary protection
Sust-C-8: Establish in-situ consumable & food production
Sci-D-13: Assess effect on plants of long-duration exposure to the lunar environment

# Lunar $O_2$ Demand

- Crew habitat and EVA $O_2$ requirements
  - 1000 kg/yr supports closing life support system for crew of 4
- Ascent Propulsion $O_2$ requirements
  - 6000 -7000 kg/yr supports two Altair ascent stages to LLO per yr
  - ? Kg/yr to support reuse of Altair descent stage for return to LLO
- Crew habitat, EVA, and Small Pressurized Rover water ($H_2O$) requirements
  - 350 – 400 kg/yr ave. $H_2O$ needed to life support system for crew before permanent stay
  - 4700 kg/yr $H_2O$ needed after permanent stay starts

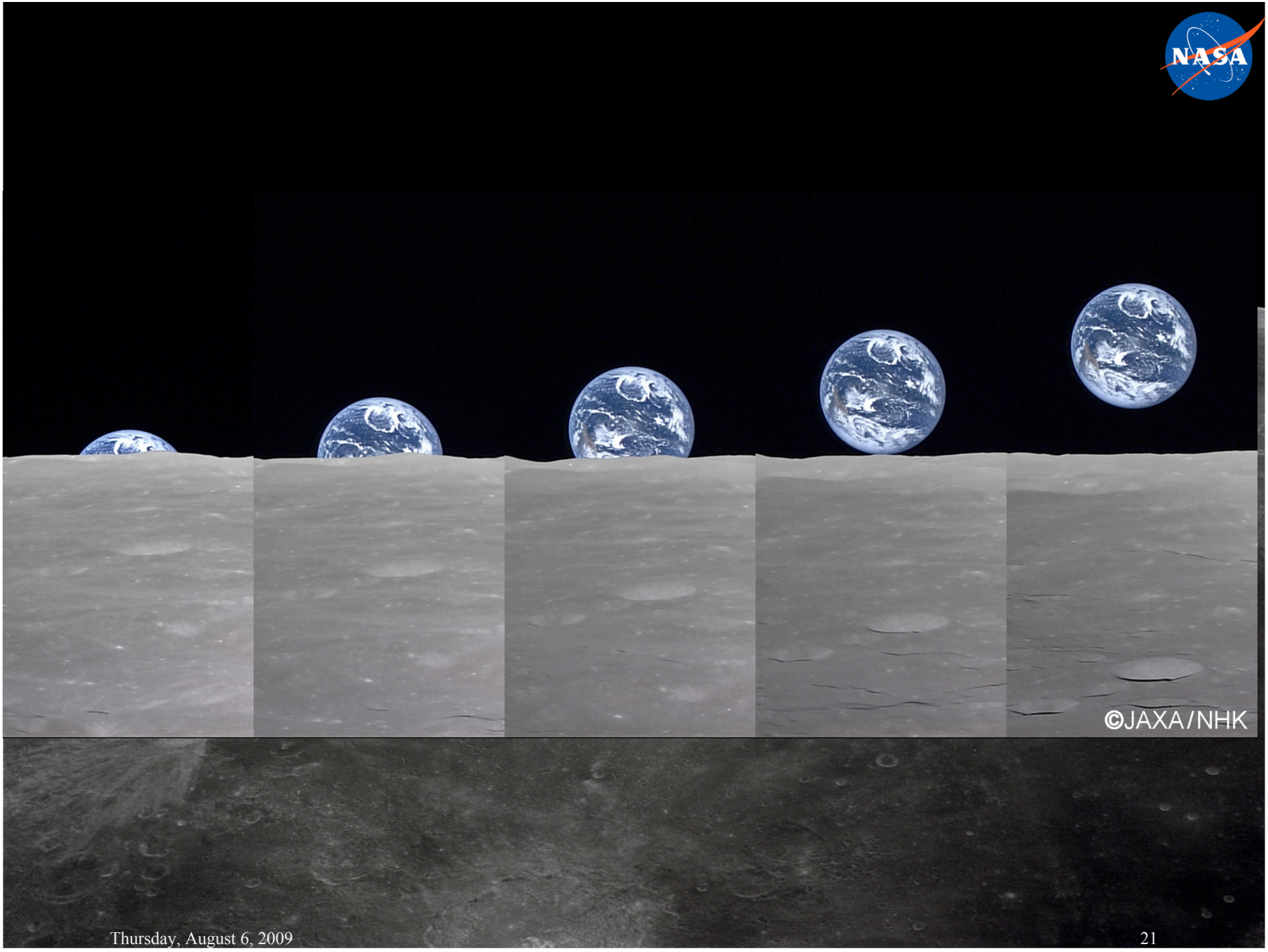
❖ Note: ~450 kg $H_2O$ extra per mission possible by scavenging remaining hydrogen ($H_2$) from Altair descent tanks and adding 400 kg of $O_2$ from ISRU; 1350 kg $H_2O$ with 1200 kg ISRU $O_2$ for 3 missions per year

# Assumptions


- This analysis covers the period 2020-2030 based on first crewed landing in 2020
- No other ISRU products are considered
- Option 1 assumes only transportation cost no dev or ops cost
- No Lunar water assumed in this analysis
- Two 50kg $O_2$ extraction and storage demo missions are included in the ISRU development costs
  - ISRU demos used to buy down risk
  - Demo flights costed at $1M/kg development and $1M/kg lunar transport
- ISRU production unit assumes "Constellation price" for Lunar surface delivery of $150k/kg and development cost of $250k/kg
- ISRU production plant will be operational prior to 2020
- ISRU operations replacement mass is 15%/year
- For initial assessment…ISRU development and operation is government funded/contractor developed/operated using standard FAR procurements

# RANPC Analysis Results

| | Development ($B) | Transportation ($B) | Operations 11 yrs ($B) | Total ($B) |
|---|---|---|---|---|
| Option 1A 2T/yr Ares 5 | 0 | 3.3 | 0 | 3.3 |
| Option 1B 9T/yr Ares 5 | 0 | 14.9 | 0 | 14.9 |
| Option 2A 2T/yr ISRU | .45 | .15 (1000kg) | .644 | 1.24 |
| Option 2B 9T/yr ISRU | .8 | .36 (2400kg) | 1.69 | 2.85 |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