FUTURE TECHNOLOGIES: SYNTHESIS

Wednesday, March 1, 2017 – 1:00 p.m.

Moderator:	Tony Freeman
Panel Members:	Brook Lakew
	Jay Falker
	Elizabeth Turtle
	Deborah Amato (synthesizer)

Themes/Categories of Technology

- Instrumentation
- Platforms - Architectures
- Flight System Technology
  - Communications, Infrastructure
  - Power
  - Many others
- Extreme Environments
- Advanced Propulsion/Transportation
- Synergy with HEOMD/Commercial Space
- Additional observations

"A lot of the technologies that we need for the things that we are going to talk about this week will take more than a decade to mature."

Topics from the Technology Poster in the Lobby

- Life detection – "non-DNA specific detection approaches"
- *In situ* measurements – "multipoint measurements"
- Applied planetary science – "small sat instrument for composition"
- Remote sensing measurements – "metamaterials based instrument"
- Mobility and access – "1,000 km range rovers"
- Power generation – "Fuel Cells!"
- Communications – "small sat optical comm"
- Contamination control – "self-DHMR w/ heaters in field"
- Navigation – "'Fire-n-Forget' navigation - tell us when you get to destination"
- Sample return – "cryogenic SR capability"
- Propulsion – "laser propulsion"
- Access to space – "how to lower access to space cost?"
- Autonomy – "optimize science collection"

Instrumentation

- Life detection – new tools and methods
    - Look for biosignatures at nanoscale
    - Advanced mass spectrometers
- *In situ* measurements
    - Planetary cores
- Remote sensing – better spectra, better resolution, better models
- **Miniaturization**
- Sample return
    - Sample retrieval and handling
        - Tools, systems, encapsulation and return
        - Scooping and digging
        - Sampling on slopes
        - Melting subsurface ice
        - Immersive virtual reality for sample selection/collection
    - Cryogenic sample return
    - Sample return from the outer solar system
- Automated microfluidic systems

Instrumentation cont.

- Advanced instruments (asteroids):
  - High definition imaging camera
  - Space-qualified spatial heterodyne spectrometer
  - Array of seismometers
  - Penetrator package
- Advanced laboratory analytical tools (+sustainability)
- Sample analysis instrumentation needs:
  - In 2020s: Provide elemental, molecular, isotopic info at scales down to a single atom; preserve organics, hydrated minerals
  - In 2030s: Vacuum transfer, at 100K (measurement of water ices/volatile organics, pristine irradiated surfaces)
  - In 2040s: Be able to do everything at 10K
  - Take advantage of new cryoelectronics, thermoelectronics
- Improved signal detection, noise rejection, new detectors, new vantage points
- Printable instruments and electronics

Platforms - Architectures

- Develop multi-target mission architectures
    - e.g. Large s/c carrying probes to be dropped off at various locations
- Establish solar-system-wide **infrastructure** for communications and navigation
- The Moon
    - Laboratory for planetary science
    - Training ground for the solar system exploration
- Extraordinary **apertures**
    - Leverage large observatories
    - In-space and self-assembly of structures
- New remote sensing methods
    - Starshade with tightly aligned telescope
    - Solar gravity lens

Platforms – Architectures cont.

- Long-term environmental monitoring
  - Pristine environmental characterization
- Mother-daughter spacecraft
  - Queen bee – swarm spacecraft system
- **Smallsats**, cubesats, chip sats/femtosats
  - Distributed sensors, multi-point measurements
- Modular/standard spacecraft with standard interfaces/volumes for customized instruments
- "Sciencecraft"
- Reduce mission and access to space costs

Flight System Technology

- Advanced communications needed
- ISRU methods – water, fuel, building material
- **Autonomous operations**, landing and hazard avoidance; fully autonomous spacecraft
- Entry, descent/ascent, and landing; Aerocapture
- Mobile submersibles – technology development not needed, difficulty is getting them into the (distant) ocean
- Contamination control/planetary protection
- Hard landers and penetrators

Flight System Technology cont.

- MEMS manufacturing
- Advanced manufacturing (3D printing)
- Ubiquitous intelligence in machines
- Quantum computing
  - Big data mining
- On-board signal processing
- Scalable robotic systems: Lander/rover access, mobility and robustness
- Power
  - Energy storage (all-temperature)
  - Compact Radioisotope Thermoelectric Generators
  - Surface power systems
  - Advanced power for outer solar system bodies (KBO)

Advanced Space Computing

Extreme Environments

- High temperature electronics
- High temperature and low temperature
- High pressure operations
- Radiation tolerance
- Highly corrosive environment
- Unknowns in the environment…

Advanced Propulsion/Transportation

- Access to new terrains (Mars)
- **Propulsion technology** to get to the outer planets
  - Robotic missions and Humans
  - Launch energy and delta-V challenges for Mercury too
- Aerial mobility
- Mobile *in situ* exploration
- Radioisotope electric propulsion
- Photonic propulsion

Synergy with HEOMD/Commercial Space

- Human spaceflight program needs to work hand in hand with Science program
  - In-space assembly of large structures
- ISRU – *in situ* resource utilization
- Human-aided sample retrieval/return
- SLS – Space Launch System (heavy lift)
- Orion crew vehicle
  - Use as relay for surface activity (rover)

Additional Observations

- Advance planetary climate models to global system models
- Build models that merge datasets from sample analysis, experimentation, and remote sensing/telescopic/robotic observations
- Use the Moon as a testbed for technology
  - And for Human-aided science elsewhere in the solar system
- On the verge of breaking through a barrier of risk aversion and sending smaller, less reviewed s/c to space
- Do we need a Technology Decadal?

Technology Plans and Roadmaps

- Ocean Worlds has a technology development plan
- Mercury Lander report from 2010
  - High temperature
- Venus Technology Plan
- Mars 2020-2050 Exploration roadmap
- Others to include?

Common threads

“All means of exploration should be integrated together.”

- Collaboration and working together
  - Between the various disciplines of Planetary Science
  - Between engineering and science
  - Between the sciences: Planetary, Helio, Astro, Earth
  - Between Human Exploration and Planetary Science
  - Leverage commercial space developments
  - Diversity of workforce is important
- We can’t do everything all at once
  - Maintain a balanced and prioritized program
  - Budget (and political) constraints should be considered

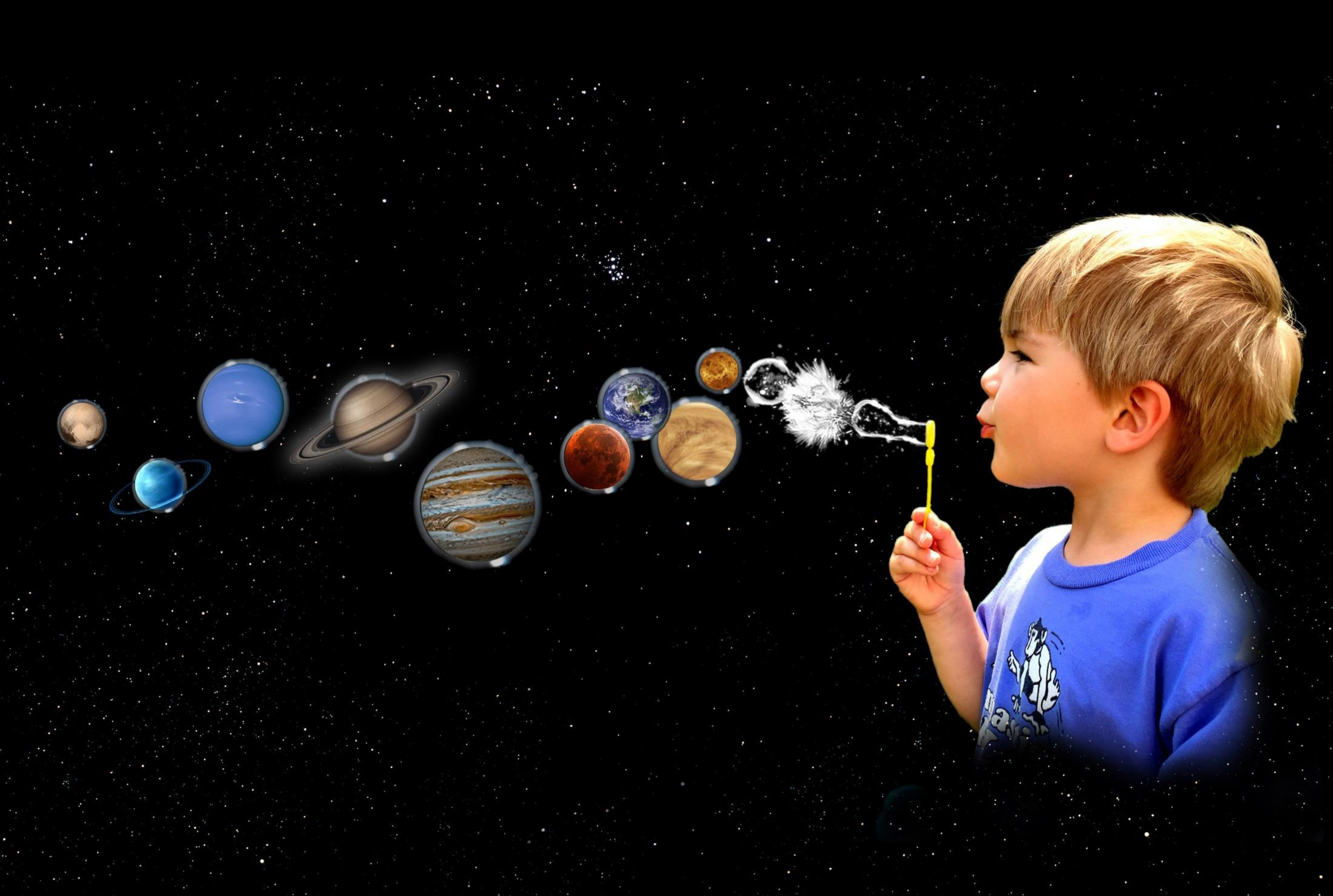

Image –J Oleary, ,M Amato inspired by PSD