Evolution to Space

Jacob Cohen, Ph.D.
Chief Scientist
NASA Ames Research Center
Disruptive Events
Lead To New Opportunities
Standardization Speeds Up The Evolution Wheel

Inheritance, Variation and Selection
Standardization does not mean regulation.

**Standardization:** The process of developing and implementing technical standards. The goals of standardization can be to help with independence of single suppliers (commoditization), compatibility, interoperability, safety, repeatability, or quality. (en.wikipedia.org)

**Regulation:** A principle, rule, or law designed to control or govern conduct. (thefreedictionary.com)
Modularization = Predictability of Standardization + Flexibility of Subcomponent Customization
A method to maximize the science return from the ISS while reducing risk, schedule and ultimately cost per experimental unit.

Reference: WetLab 2, NanoLab and Cell Science hardware as proposed by J. Cohen
Nov. 3, 1957
Laika, first animal in space

July 21, 1969
Armstrong and Aldrin on the Moon

April 12, 1961
Gagarin first human in space

The March 22, 1952 issue of Collier’s Magazine

“Moon Landscape” by Petr Ginz (1942)
Microgravity and Moss Growth

On Earth

Gravitropic *Ceratodon purpureus* moss cells default to spiral growth in spaceflight microgravity.

Gene array. Each cell culture condition including microgravity (A) and terrestrial rotating wall vessel (B) is compared with a static nonadherent bag culture. Sheer stress proteins and heat shock proteins are shown in green, and transcription factors are in red. More than 1,600 (1,632) change more than the specific threshold of threefold up and down in the flight (microgravity) culture (A) and more than 900 genes (914) changed in the terrestrial RWV culture (B); only a few genes (5) changed in a terrestrial centrifuge culture (not shown).

(Hammond, 2000)
Formation of large prostate cancer organoids with the 3D rotating wall vessel bioreactor in space. Much larger prostate organoids were formed in space (30-50 cm across) as compared to the parallel ground study (3-5 cm) despite no difference in glucose utilization rate between ground and space studies.

(Wang, 2005)
Transitory virulence increase of *S. typhimurium* in response to spaceflight in LB medium is not observed in M9 minimal medium or LB medium supplemented with M9 salts.

(Nickerson Lab; STS-115 and STS-123)
Examples of Human Responses to Space

- Intra-Cranial Pressure
- Neuroplasticity
- T-Lymphocyte Immunosuppression
- Reproductive System Changes
- Slow/Fast Fiber Change
- Bone Remodeling
- Spinal Learning
- Virulence
As of February 27, 2012
1,790 host stars
2,321 planet candidates
74 confirmed planets
### Mass Breakdown Requirements (Per Person-Day)

**DAILY INPUTS - NOMINAL**

<table>
<thead>
<tr>
<th>Item</th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>0.84</td>
</tr>
<tr>
<td>Food Solids</td>
<td>0.62</td>
</tr>
<tr>
<td>Water in Food</td>
<td>1.15</td>
</tr>
<tr>
<td>Food Prep Water</td>
<td>0.79</td>
</tr>
<tr>
<td>Drink</td>
<td>1.62</td>
</tr>
<tr>
<td>Hand/Face Wash Water</td>
<td>1.82</td>
</tr>
<tr>
<td>Shower Water</td>
<td>5.45</td>
</tr>
<tr>
<td>Clothes Wash Water</td>
<td>12.50</td>
</tr>
<tr>
<td>Dish Wash Water</td>
<td>5.45</td>
</tr>
<tr>
<td>Flush Water</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>30.74</strong></td>
</tr>
</tbody>
</table>

**DAILY OUTPUTS - NOMINAL**

<table>
<thead>
<tr>
<th>Item</th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>1.00</td>
</tr>
<tr>
<td>Respiration and Perspiration Water</td>
<td>2.28</td>
</tr>
<tr>
<td>Urine</td>
<td>1.50</td>
</tr>
<tr>
<td>Feces Water</td>
<td>0.09</td>
</tr>
<tr>
<td>Sweat Solids</td>
<td>0.02</td>
</tr>
<tr>
<td>Urine Solids</td>
<td>0.06</td>
</tr>
<tr>
<td>Feces Solids</td>
<td>0.03</td>
</tr>
<tr>
<td>Hygiene Water</td>
<td>6.68</td>
</tr>
<tr>
<td>Clothes Wash Water</td>
<td>11.90</td>
</tr>
<tr>
<td>Clothes Wash</td>
<td>0.60</td>
</tr>
<tr>
<td>Latent Water</td>
<td>0.60</td>
</tr>
<tr>
<td>Other Latent Water</td>
<td>0.65</td>
</tr>
<tr>
<td>Dish Wash Water</td>
<td>5.43</td>
</tr>
<tr>
<td>Flush Water</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>30.74</strong></td>
</tr>
</tbody>
</table>

**Life Support**

11.3 Metric Tons Per Person-Year
Biology is the right tool for exploration

- Low mass
- Self replicating
- Fast growing
- Adaptable
- Flexible host
- A manufacturing technology
The Potential of Synthetic Biology in Space

- Optimized Food Production
- Cell Based Biomaterials Production
- Regolith Biomining
- Biocementation
- DNA Sequence Transceiver and In Situ Synthesis
- Radiation Resistant Habitats
- Multipurpose Microbial Bioreactors
- Environmental Monitoring and Biosensors
- Water Treatment
- Waste Management
- Biomanufacturing and Programming Pattern Formation
- Air Treatment
Bioelectrochemical systems utilize microorganisms that are capable of generating electricity during the catalysis of substrates (microbial fuel cell - MFC) and/or utilizing electrical energy as the metabolic energy source for growth (reverse MFC).

Take it a step further: How about a synthetic biology ion engine?
The key to long term success in life is imagination, persistence, and compassion.

From the Past
From the Future
The Drive of Now
Working Together Humanity Will Conquer
The Exploration of the Time and Space Frontier

Thank You
NASA Ames Research Center
Ames Today

- Science
  - Space, Earth, Biological Sciences
  - Astrobiology, Lunar Science

- Exploration Systems
  - Exploration Technology Development
  - Thermal Protection Systems
  - Supercomputing

- Projects and Missions

- Aeronautics & Aviation
  - NextGen Airspace Systems
  - Fundamental Aeronautics
  - Aviation Safety
  - Green Aviation

- Affordable Small Satellites

- Innovation, Education, & Entrepreneurial Collaborations
  - NASA Research Park

-2480 employees*
-~900M + annual revenue
  (including reimbursable)
*in addition, 900 students, summer 2012
Current Active Facilities, 2009

- National Full Scale Aerodynamic Complex, 80x120 Wind Tunnel
- Vertical Motion Simulator
- Small Spacecraft Development Facility
- Unitary Plan Wind Tunnel
- SOFIA
- Machine Shops
- Small Satellite Lab
- Pleiades - Columbia Super Computer
- Ballistic Range
- Arc Jets
- Airfield and Hangars

Image copyright Dariusz Jezewski
Astrobiology Institute

NASA Lunar Science Institute

NASA Aeronautics Research Institute

Scientific Study of life

Advance the field of lunar science

Creating new tools and technologies for reducing air traffic congestion and environmental impacts, improving safety, and designing aircraft
NASA Research Park

Innovative Collaboration in Science, Engineering & Education

90+ Partners Today

University Associates
Google-North East Section
University of California/UARC-Bldg. 555
M2MI Corporation-Bldg. 19
Carnegie Mellon University-Bldg. 23
San Jose State University
Metropolitan Technology Center in Bldg. 583C
Foothill-De Anza Community College
United Negro College Fund Special Programs Corporation-Bldg. 19
Space Technology Center
San Jose State, Stanford, Santa Clara Univ.,
Utah State Univ./Micro Satellite Classes
Kentucky Science & Technology Corporation-Bldg. 19
Bloom Energy-Bldg. 543 (Fuel Cell Research)
Industry Partners-Bldg. 566 & 19
UAV Center-Bldg. 18
International Space University
WHY WE DO WHAT WE DO—PART ONE
FOUR THINGS NASA DOES
Number One: Improve Life on Earth

- Aeronautics
  - Next Gen
  - Environmentally Responsible Aviation
  - New Initiatives
    - Autonomy, Electric Aviation
- Earth Climate studies
  - Site-specific Climate prediction
Number Two: Conduct Earth and Space Science

- Astrophysics
  - Origin/Distribution of Life in the Universe
- Planetary science
  - Moon
  - Mars
  - Asteroids
- Earth Science
  - Venture class
- Heliospheric Physics
  - IRIS
Number Three: Human Space Exploration

- Fundamental Biology
- Entry, Descent & Landing
- Human Factors
Number Four: Cross Cutting Initiatives

- High end computing (quantum)
- Synthetic Biology
- Innovative Partnerships
  - DoD
  - Industry
  - International / Academic
Ames Contributions to Aeronautics

Flight Research
Cooper-Harper Rating Scale
Wind Tunnel Testing
Flight Simulation
Swept Wings

Conical Camber
Computational Fluid Dynamics
Short-Haul Aircraft
Takeoff Research
Air Traffic Management
Ames Contributions to Air Traffic Management

- Products
  - Traffic Management Advisor Build 1
  - Flight Management Systems
  - Optimal Guidance
- Research Spectrum
  - Scheduling Algorithms
- Final Approach Spacing
  - Human Factors
- Future Automated ATC
- Intelligent Software
- Arrivals Metering
- 1994
- 1990
- 1980
- 1970
- 1973
Ames Contributions to Mercury and Gemini

Blunt Body Re-entry
Free Flight Ablation Test
Arc Jet Facility

Re-entry Aerodynamics
Tektites and Trajectory Studies
Dean Chapman

Re-entry Airflow and Stability Pattern Studies
Hypervelocity Free-Flight Facility

Shadowgraph
Project Mercury Re-entry Capsule

Shadowgraph
Project Gemini Re-entry Capsule

Spacecraft Testing and Evaluation
Unitary Plan Wind Tunnel
Ames Contributions to Apollo

Technology Research

- Free Flight Ablation Test, Blunt Body Re-entry Studies
- Steerable Parachute
- Navigation Simulator
- Launch Escape System Unitary Plan WT
- Guidance System

Moon Sample Analysis

- Lunar Surface Magnetometer
- Dr. Cyril Ponnamperuma Analyzing Moon Sample
- Life Sciences Glove Boxes, Lunar Receiving Facility
**Ames Contributions to the Space Shuttle**

### Supporting Research
- **Lifting Bodies**
- **Orbiter/Boeing 747 Ferry Configuration 14-foot WT**
- **Exhaust Plume Interactions 9 x 7 WT**
- **Shuttle Abort Maneuver 14-foot WT**
- **TPS Materials Development**
- **Stagnation Point Tests Arc Jet**

### Aerodynamics
- **Shadowgraph of Bow Shock Wave at Mach 7**
- **Simulation on Hyperwall**

### Ascent Aerodynamics & Aero thermodynamics
- **CFD Simulation Results for the Shuttle Stack During Ascent**
- **Ames-Dryden Flight Research Center**
- **Shuttle Landing Site (38 Landings between 1981-1994)**

### Low-Speed Descent Aerodynamics
- **36 Percent Scale Model 40 x 80 WT**
- **Vertical Motion Simulator**

### Flight Simulation
- **Columbia Supercomputer, Wind Tunnels, Debris Transport, Ascent Aerodynamics, Thermal Protection Experts, Thermal Analysis, Structural Analysis, Database Management, and Virtual Motion Simulator**

### Return to Flight
- **Standby Support During Missions**
Ames Contributions to Astrobiology

Investigation into:

- Context for habitable environments and life
- Origins of life and its impact on the planetary environment
- Future of life in changing environments

*Excerpted from 2003-2004 NAI ARC team report

Dr. Harold P. Klein
Dr. Cyril Ponnamparuma
Dr. Baruch Blumberg
Dr. David Morrison
G. Scott Hubbard

Kepler
Spitzer Space Telescope
Airborne Science Platforms
Robots and Other Instruments
Orbiters and Probes

Earth, the Moon, Mars, and other planets

Stars
Meteors & Comets
Asteroids
**Ames Contributions to Lunar Exploration**

**Apollo 1969**
- Safe human landing on the Moon and return to Earth
- Guidance System
- Lunar Surface Magnetometer
- Blunt Body Re-entry
- Moon Sample Analysis (Lunar Receiving Facility)
- Launch Escape System

**Lunar Prospector 1998**
- Spectroscopic survey of entire lunar surface
- Mission and Operations
- Managed Payload, Instruments, and Spacecraft Design and Development

**LCROSS 2008**
- Confirm presence or absence of water or ice in a polar lunar crater
- Mission and Operations
- Managed Payload, Instruments, and Spacecraft Design and Development

**Constellation**
- Human exploration of the Moon, Mars, and beyond
- Orion CEV
  - Thermal Protection System
  - Aero/Aero-thermal Database
  - Flight Software and Guidance, Navigation and Control
- Mission Operations
  - Flight Control Software
  - Training Applications
  - Planning and Development Tasks

**Technology and Science Support**
- Lunar Crater Observation
- Exploration Life Support
- Radiation Dosimetry and Medical Sensor Technology
- Space Human Factors
- ISS Exploration Experiments
- Piloted Spacecraft Handling Reentry

**Ares I**
- Integrated Systems Health Mgmt.
- Launch Abort System Software and Instrumentation
- Aero/Aerothermal Models and Analysis and Risk Assessments

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**Contributions to Lunar Exploration**

Palmer Dyal
Apollo Lunar Surface Magnetometer

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**NASA Lunar Science Institute**
**March 2008**
Ames Contributions to Mars Exploration

- Dr. Harold P. Klein
- Early Tests for Mars/Venus Entry in Carbon Dioxide and Nitrogen Mixtures (Early 1960s)
- Biological Investigation (Viking)
- Thermal Protection Systems (MER and MSL)
- Science Operations (MER)
- Mission Support Software (MER)
- Landing Site Selection (MER)
- Shadowgraphs showing the shock wave shape
- Human-Centered Computing and Fatigue Countermeasures (MER)
- Parachute Wind Tunnel Tests (MER and MSL)
Ames Contributions to MSL

Mars Science Laboratory Entry, Descent, and Landing Instrument (MEDLI)
Sophisticated plugs with multiple temperature sensors that measure atmospheric conditions and performance of the heat shield

PICA Heat Shield

Mars Science Laboratory InterfaCE (MSLICE)
Software tool to plan the science activities of the Mars rover and maximize scientific research

Parachute test

CheMin
Ames Contributions to Small Spacecraft

**Pioneer 6-9**
1965-1968
Studied the solar wind from a solar orbit.

**Pioneer 10 & 11**
1972-1973
First man-made objects to safely pass the asteroid belt, provide detailed investigation of Jupiter and Saturn, and, leave our solar system.

**Pioneer Venus**
May 1978
Completed radar mapping of 93% of the planet's surface. The four probes and bus gathered data about the Venusian atmosphere.

**Lunar Prospector**
1998
Carried out a spectroscopic survey of entire lunar surface.

**SOAREX**
2004-
Conduct suborbital aerodynamic reentry experiments.

**GeneSat**
2006
Miniature satellite provided life support to E.Coli bacteria in orbit.

**NanoSail-D/PreSat**
2008
Demonstrate and validate performance of the platform.

**PharmaSat**
2008
Miniature satellite will carry yeast spores.

**LCROSS**
2008
Confirm presence or absence of water or ice in a polar lunar crater.

**LADEE**
2011
Assess the atmosphere and surface dust of Earth's moon.