# Open Innovation and Collaboration - NASA Human Health and Performance

## *Possible Applications of Biomimicry*

## International Biomimetics Conference

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# NASA Human Health and Performance (HH&P) Strategy Formulation and Execution

# Formulating and Executing our Strategy

- Strategic Plan (2007 and 2012)
  - Develop an improved business model using collaborative approaches to drive health innovations in space and on Earth
- Benchmark to inform implementation
  - Culture change most critical for success
  - Collaboration needed to drive innovation
- Successful open innovation pilots testing new approaches to solving technical problems
- NHHPC, NTL and CoECI: virtual centers built to advance collaboration and the use of open innovation
- Solution Mechanism Guide (SMG) Tool to integrate new tools into HH&P culture

# Human Health and Performance Directorate

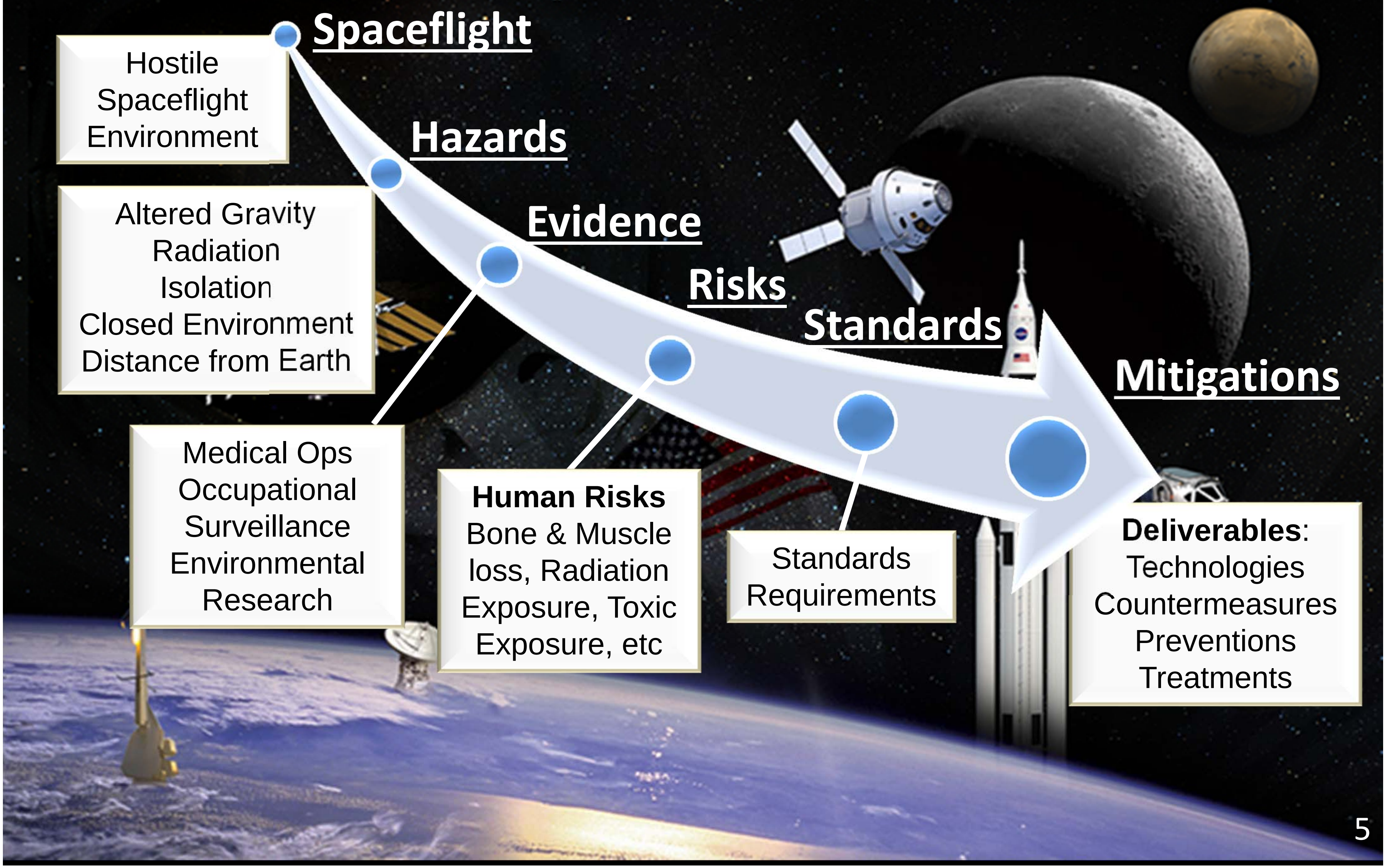
HH&P Organization

- Space and Clinical Operations
  - Health care and medical systems
- Biomedical Research and Environmental Sciences
  - Physiological, environmental and behavioral effects of spaceflight

- Human Systems Engineering and Development
  - Human centered design (hardware/software), human factors, food systems


# NASA Human Health and Performance

## Goal: Enable Successful Space Exploration by Minimizing the Risks of Spaceflight Hazards

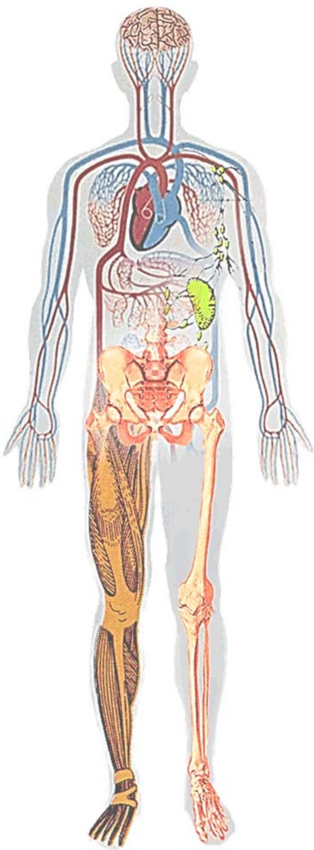


# Hazards of Spaceflight

## Hazards Drive Human Spaceflight Risks

### Altered Gravity - Physiological Changes

Balance Disorders
Fluid Shifts
Cardiovascular Deconditioning
Decreased Immune Function
Muscle Atrophy
Bone Loss



### Distance from earth

Drives the need for additional "autonomous" medical care capacity – cannot come home for treatment

### Space Radiation

Acute In-flight effects
Long term cancer risk

### Hostile/ Closed Environment

Vehicle Design
Environmental – $CO_2$ Levels, Toxic Exposures, Water, Food

### Isolation & Confinement

Behavioral aspect of isolation
Sleep disorders

# Summary of Human Risks of Spaceflight
# Grouped by Hazards – 30 Human Risks, 2 Concern/Watchlist Items

## *Altered Gravity Field*

**Primary Effect**

1. **Spaceflight-Induced Intracranial Hypertension/Vision Alteration**
2. Urinary Retention
3. **Space Adaptation Back Pain**
4. Renal Stone Formation
5. **Risk of Bone Fracture due to spaceflight Induced bone changes**
6. Impaired Performance Due to Reduced Muscle Mass, Strength & Endurance
7. **Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity**
8. Impaired Control of Spacecraft, Associated Systems and Immediate Vehicle Egress due to Vestibular / Sensorimotor Alterations associated with space flight.
9. **Cardiac Rhythm Problems**
10. Orthostatic Intolerance During Re-Exposure to Gravity
11. Adverse Health Effects due to Alterations in Host Microorganism Interaction

**Concerns/Watchlist**

1. **Concern of Clinically Relevant Unpredicted Effects of Medication**
2. **Intervertebral Disc Damage**

## *Radiation*

**Primary Effect**

1. **Risk of Space Radiation Exposure on Human Health**

## *Distance from Earth*

**Primary Effect**

1. **Unacceptable Health and Mission Outcomes Due to Limitations of In-flight Medical Capabilities**
2. Risk of Ineffective or Toxic Medications due to Long Term Storage

## *Isolation*

**Primary Effect**

1. **Risk of performance decrements due to adverse behavioral conditions**

## *Hostile/Closed Environment-Spacecraft Design*

**Primary Effect**

1. **Toxic Exposure**
2. Acute and Chronic Carbon Dioxide Exposure
3. **Hearing Loss Related to Spaceflight**
4. Risk of reduced crew performance prior to adaptation to mild hypoxia.
5. **Injury and Compromised Performance due to EVA Operations**
6. Decompression Sickness
7. **Injury from Sunlight Exposure**
8. Incompatible Vehicle/Habitat Design
9. **Risk of Inadequate Human-Machine Interface**
10. Risk to crew health and compromised performance due to inadequate nutrition
11. **Adverse Health Effects of Lunar (Celestial) Dust Exposure**
12. Performance Errors Due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness, and Work Overload
13. **Injury from Dynamic Loads**
14. Risk of Altered Immune Response
15. **Risk of electrical shock**

| Standards | |
|---|---|
| ★ (yellow) | NASA-STD-3001, VOLUME 1, CREW HEALTH |
| ★ (green) | NASA-STD-3001, VOLUME 2, HUMAN FACTORS, HABITABILITY, & ENVIRONMENTAL HEALTH |
| ★ (blue) | Clinical Practice Guidelines |

★ Standards in process of review/change/addition

# Risk Assessment

## Bone Fracture due to Spaceflight-induced Changes to Bone

**Countermeasures: *Prevention:*** selection standard, exercise, task design, diet, pharmaceuticals. ***Treatment:*** In-flight treatment/medical kit, meds, post-mission rehabilitation

**L x C Driver: OPS Likelihood all except Planetary :** < 0.1% likelihood of bone fracture in mission due to existing countermeasures (prevention by selection ) effectiveness. **Planetary:** increases due to mission duration and surface operations**. Consequence LEO, Sortie, Lunar:** Bone fracture considered significant injury with in flight treatment and return to Earth. **Deep Space and Planetary Consequence:** Injury may be disabling due to the inability to return to Earth for treatment. **LTH Likelihood LEO, Lunar, Journey**: Likelihood of fracture due to spaceflight > 0.1% and < 1%. Most crew could return to baseline BMD within 3 years. **Sortie:** Likelihood <0.1% due to limited mission duration. **Planetary:** > 1% due to mission duration. **LTH Consequence:** Bone fracture prevention may require extended medical interventions by known methods

| DRM Categories | Mission Duration | L x C OPS | L x C LTH | Risk Disposition |
|---|---|---|---|---|
| Low Earth Orbit | 6 months | 1 x 4 | 2 x 3 | Accept |
| | 1 year | 1 x 4 | 2 x 3 | Accept |
| Deep Space Sortie | 1 month | 1 x 4 | 1 x 3 | Accept/ Optimize |
| Lunar Visit/ Habitation | 1 year | 1 x 4 | 2 x 3 | Accept/ Optimize |
| Deep Space Journey/Hab | 1 year | 1 x 4 | 2 x 3 | Accept/ Optimize |
| Planetary | 3 years | 2 x 4 | 3 x 3 | Mitigate |

| Deliverables Required | Responsible Program | Budget ($M)/ (2014-2018) |
|---|---|---|
| **Knowledge:** | | |
| • Surveillance data to supplement bone density with bone quality index | HRP/Grant | |
| • Identify critical risk factors | HRP/Grant | |
| **Countermeasures — Technology:** | | |
| • Develop biomarkers | HRP/Grant | |
| • Need to establish index for CM efficacy | HRP/Contract | |
| • Evaluate pharmacological CMs | HRP/Grant | |
| **Countermeasures — Operational Protocols:** | | |
| • Continued crew monitoring | ISS/CHS/HRP | |
| **Countermeasures — Guideline/Requirements/Standards:** | | |
| • Leverage terrestrial Level 4 Evidence | CHS/HRP | |

# HH&P Open Innovation Pilot Projects:

## *Innovation Malls, Innovation Communities, and Consortiums*

# Portfolio Analysis: Models of Collaboration

## The Four Ways to Collaborate

There are two basic issues that executives should consider when deciding how to collaborate on a given innovation project: Should membership in a network be open or closed? And, should the network's governance structure for selecting problems and solutions be flat or hierarchical? This framework reveals four basic modes of collaboration.

| PARTICIPATION | GOVERNANCE: Hierarchical | GOVERNANCE: Flat |
|---|---|---|
| Open | **Innovation Mall**<br>A place where a company can post a problem, anyone can propose solutions, and the company chooses the solutions it likes best<br>**Example:** *InnoCentive.com website, where companies can post scientific problems* | **Innovation Community**<br>A network where anybody can propose problems, offer solutions, and decide which solutions to use<br>**Example:** *Linux open-source software community* |
| Closed | **Elite Circle**<br>A select group of participants chosen by a company that also defines the problem and picks the solutions<br>**Example:** *Alessi's handpicked group of 200-plus design experts, who develop new concepts for home products* | **Consortium**<br>A private group of participants that jointly select problems, decide how to conduct work, and choose solutions<br>**Example:** *IBM's partnerships with select companies to jointly develop semiconductor technologies* |

HARVARD BUSINESS REVIEW • DECEMBER 2008

Gary Pisano,
Harvard Business School

# Open Innovation

- Why Open Innovation?
  - Joy's Law
    - "No Matter Who You Are, Most of the Smartest People Work for Someone Else"
      – Bill Joy, Cofounder Sun Microsystems
  - The Causal Explanation for Joy's Law
    - Knowledge is unevenly distributed in society - Fredrich von Hayek (1945)
    - Knowledge is sticky - Eric von Hippel (1994)
      – from Karim Lakhani, PhD Harvard Business School

# Portfolio Analysis

- HH&P Research and Technology Development Portfolio Gaps
  - Food packaging to maintain quality for 5 years
  - Compact (one cubic foot, 20 pound) exercise device for capsules
  - Solar proton event predictive capability for 24 hours
  - Coordinated sensor swarms for planetary research
  - Accurate tracking of medical consumables in flight
  - Motivational enhancement for exercise
  - Inflight laundry system

# Open Innovation Pilot Projects

- **InnoCentive**: posts individual challenges/gaps to their established network of solvers (~300,000)
  - financial award if the solution is found viable by the posting entity
- **Yet2.com**: acts as a technology scout bringing together buyers and sellers of technologies
  - Option to develop partnerships
- **TopCoder**: open innovation software company with a large network of solvers (~300,000)
  - variety of skill-based software coding competitions
- **NASA@work**: internal collaboration platform leveraging expertise found across NASA's 10 centers

# HH&P Open Innovation Pilot Projects:

## *Innovation Malls, Innovation Communities, and Consortiums*

INNOCENTIVE®

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InnoCentive Challenges | Pavilions | External Challenges

# NASA Innovation Pavilion


NASA Pavilion Home | NASA Challenges

# Global Appeal-

2900 solvers

80 Countries

# InnoCentive Successes

| Challenge | TRL* | Submissions | Award |
|---|---|---|---|
| **Data-Driven Forecasting of Solar Events (D. Fry)**<br>➢ Resulting model showed a high percent correct (~95%) but with an equally high false alarm rate. Potential for coupling with other modeling efforts | Low | 11 | $30,000 |
| **Non-invasive Meas of Intracranial Pressure (S. Villarreal)**<br>➢ Resulted in a predictive algorithm from UCLA using available physiologic data. Site visit planned to assess UCLA analysis of NASA data via modification of existing NSBRI study. | Med | 638 | $15,000 |
| **Compact Aerobic Resistive Exercise Device Mech (L. Loerch)**<br>➢ Technology was included in Advanced Exercise Concepts trade space for consideration | Low | 95 | $20,000 |
| **Food Packaging and Protection (M. Perchonok)**<br>➢ Monitoring other packaging team evaluations of flexible graphene material proposed as solution | Med | 22 | $11,000 (partial) |

***TRL = Technology Readiness Level**
**Low (1-3), Med (4-6), High (7-9)**

# yet2.com Successes

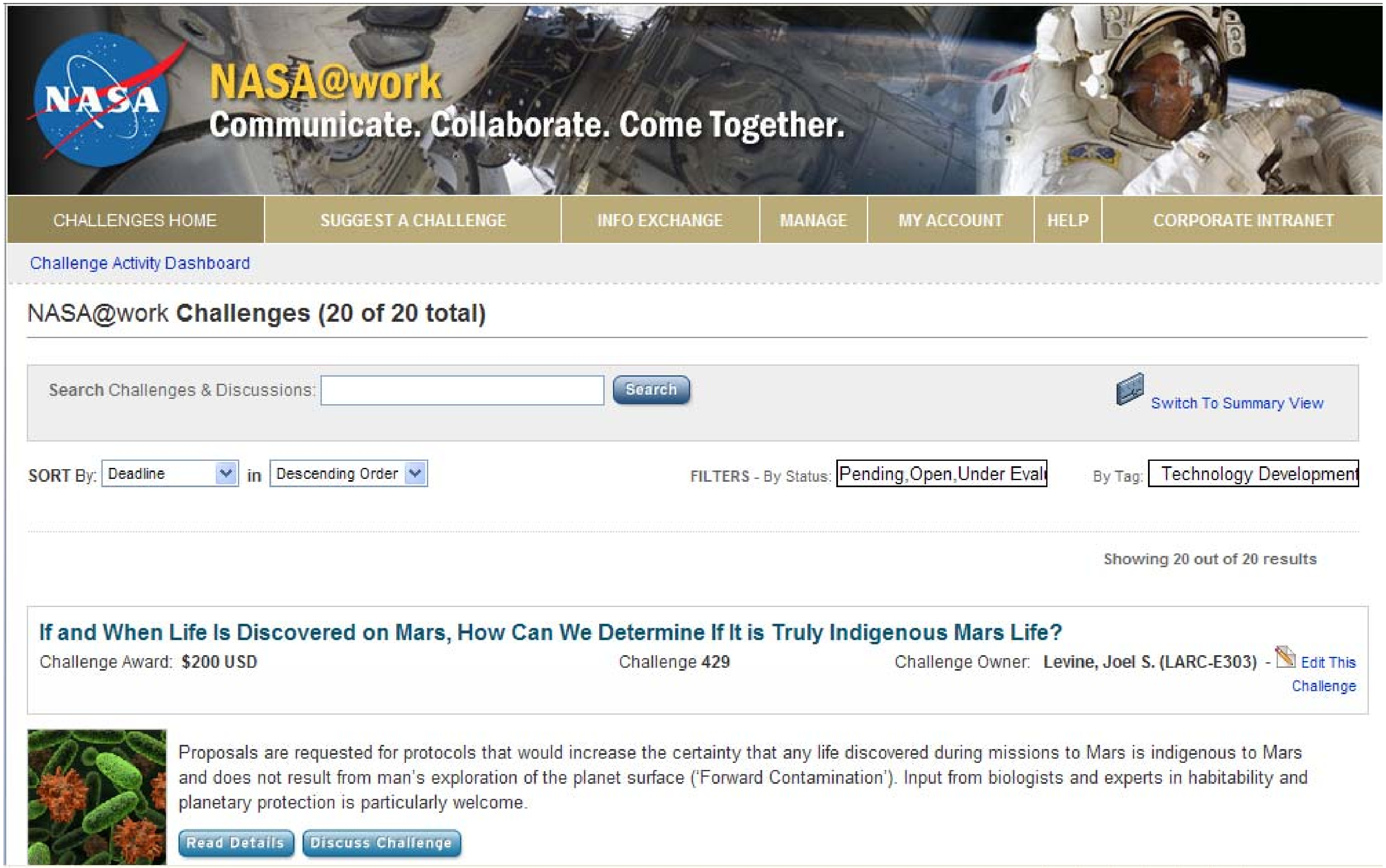
| ***Technical Need*** | ***TRL**** | ***Total Leads*** | ***Active Leads*** |
|---|---|---|---|
| **Hip Bone Microarchitecture Measurement (J. Sibonga)**<br>➢ Pilot study quantifying changes in sheep bone microarchitecture for preclinical validation expected to be completed by the end of FY13<br>➢ Provides foundation for a research proposal to validate this technology in a population of spinal cord injured subjects | Med | 51 | 5 |
| **Water Disinfection and Monitoring (M. Ott)**<br>➢ Provided a status of state-of-the-art water disinfection and monitoring alternatives, which indicated a need for NASA to develop new technologies for our specialized needs during spaceflight | Low | 61 | 8 |
| **Food Packaging and Protection (M. Perchonok)**<br>➢ Evaluation of one lead as partner underway | Med | 29 | 5 |

***TRL = Technology Readiness Level**
**Low (1-3), Med (4-6), High (7-9)**

# TopCoder Pilot Project

- Opportunity presented to NASA by Harvard Business School
  - Research project to compare outcomes of collaborative and competitive teams
  - NASA provided the problem statement
    - Optimize algorithm that supports medical kit design
- Competition began in Nov 2009 and lasted approximately 10 days
  - 2800 solutions were submitted by 480 individuals
  - Useful algorithm developed and incorporated into NASA model
  - Team felt this process was more efficient than internal development
- Result: NASA Tournament Lab with HBS and TopCoder established to seek many novel optimization algorithms for ISS

# NASA@work Pilot Project



# NASA@work Successes

- Pilot conducted in 2010 and fully operational platform launched in 2011
- Connects 10 NASA centers and offers access to previously untapped expertise
- Enthusiastic response to new business model

**Challenges** (since Aug 2011)

- Number of Challenges: 56
- Winners to Date: 142
- Average Number of Posts per Challenge: ~41

**NASA@work Community** (as of April, 2014)

- Solvers: 11,090
- Active Solvers: 601

# Other HH&P Strategic Initiatives

- Rice Business Plan Competition
  - 42 MBA/technical student teams
  - Offered life science prize for earth/space benefits
    - 5 teams awarded since 2008
    - 2 teams have secured funding
      - Series A funding
      - USDA grant
- LAUNCH (NASA HQ)
  - Early stage technologies identified
  - Netra (MIT Media Lab)

# Future HH&P Initiatives

- National Science Foundation Ideas Lab
  - Rapid, iterative proposal development
  - Joint NASA-NSF Workshop December 2013
- Marblar
  - A crowd-sourcing platform seeking to repurpose “over-looked technologies” for new applications
  - Evaluating feasibility of existing technologies for new purposes

# Biomimicry as a Problem-Solving Tool

1. **<u>Someone to Ask the Question</u>:**

   **(on a regular basis)**

**"Can Nature Help us?"**

**… And**

2. **<u>Someone to Answer it</u>….**

**Natural Systems Experts with ready access to Research and Development**

Courtesy of George Studor

# Favorable Trends

Increasing trends:

1. Knowledge of Natural – Living and Non-living - Systems
2. Numbers of Experts and Organizations in Natural Systems
3. Access to Knowledge and Experts world-wide via internet and search/link tools
4. Ability to Manufacture & Mimic Biological Materials, Systems and Functions
5. Demand for highly integrated, smarter and more capable systems
6. Success Stories: Nature applied to design, engineering and operations

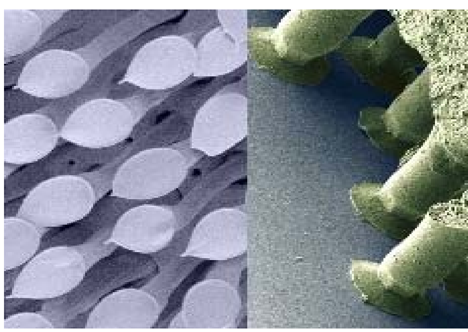
Courtesy of George Studor

# Growing: Number of Success Stories

Kingfisher[5] inspired a new shape for Japan's Shinkansen 500-Series trains[6]

Gecko feet[8] inspired Gecko-tape[9]


Beetle foot hairs[10] have inspired Beetle-tape[11]



Courtesy of
George Studor

# Possible Areas of Application

- Surface & Sub Surface Mobility: Individual, Cooperative/Swarm mobility approaches & vehicles
- Structures: Reduce Weight, Increase Toughness, Efficient /Modular Designs, Insitu manufacturing
- Materials: Nano-fabrication for Biomimicry, Self-healing
- Robotics: Intelligence, Dexterous Mechanical operations, Human-Robotic interaction
- Sensing: Remote Sensors, Embedded Sensors, Distributed Sensing, Miniaturization, Neural-Net
- Energy: Collection, Distribution, Storage, Conversion and Utilization Efficiencies
- Thermal and Environmental Controls: Efficient Structures and Materials, Thermal Insulation, Conduction, Rejection, Radiation etc.

Courtesy of George Studor

# How Can Biomimicry Applications Be Considered as Problem-Solving Tools?

*NASA Human Health and Performance Center (NHHPC)*

# About the NHHPC

➢ *Established Oct 2010*

collaborate · innovate · educate

*A global convener of government, industry, academic, and non-profit organizations to advance human health and performance innovations that enable space exploration and benefit life on Earth*

## Member Engagement Activities

- Annual workshops
- Member Webcasts
- Quarterly NHHPC eNews
- Collaborative opportunities and technical needs postings