In-Flight Laboratory Analysis

September 2012

David Baumann, HHC Element Manager, JSC
Gail Perusek, In-Flight Lab Analysis Project Manager, GRC
Emily Nelson, PhD, Project Scientist
Michael Krihak, PhD, ExMC Lab Analysis Project Lead, ARC
Dan Brown, Systems Engineering Lead, ZIN Technologies

Overview

FY11 Highlights

- Space Environment
- Human Research Program
- Risks & Functional Requirements

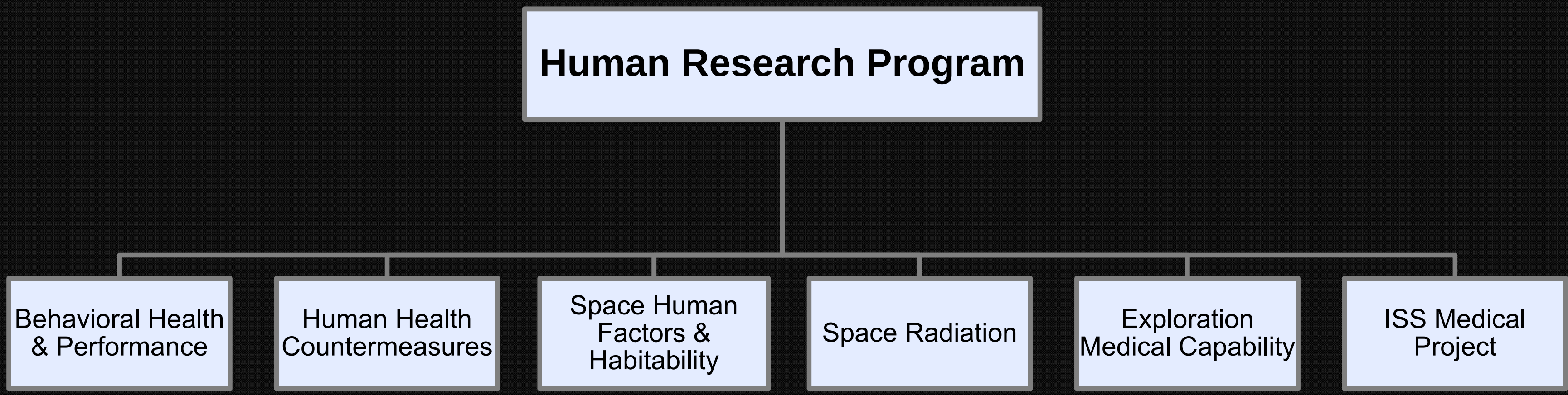
Space Environment

- Zero gravity
- Radiation
- Limited mass, volume and power
- Limited resources - water, air, food
- Communication lags or blackouts (isolation)

Clay Anderson centrifuges blood samples for a nutrition project during Increment 15

ISS030-E-257690 (26 April 2012) --- European Space Agency astronaut Andre Kuipers, Expedition 30 flight engineer, prepares for IMMUNE venous blood sample draws in the Columbus laboratory of the International Space Station.

HRP Organization & Elements



- The Program is divided into 6 major elements, which
  - Provide the Program's knowledge and capabilities to conduct research, addressing the human health and performance risks
  - Advance the readiness levels of technology and countermeasures to the point of transfer to the customer programs and organizations
- The National Space Biomedical Research Institute (NSBRI) is a partner with the HRP in developing a successful research program.

Human Research Program

Program Goals

- Perform research necessary to understand and reduce spaceflight human health and performance risks in support of exploration
- Enable development of human spaceflight medical and human performance standards
- Develop and validate technologies that serve to reduce medical risks associated with human spaceflight

Human Health and Countermeasures (Research)

Research Objectives

- Developing knowledge, capabilities, countermeasures, & technologies to mitigate highest risks to crew health & performance & enable human space exploration.
- Developing technologies to reduce medical and environmental risks, and to reduce human systems resource requirements.

- Requirements align to current gaps and tasks as defined by the IRP that are research and technology development related.
- As new knowledge is gained, the required approach to research and development may change.
  - Gaps and tasks are periodically updated, subject to change.
  - *Hence, requirements are not comprehensive and allow for flexibility as new research needs are identified and arise.*

ExMC Risk and Gap (Med Ops)

Exploration Medical Capability

- Ensure astronaut health and safety due to injury or illness on extended (>30 days) human exploration missions.

- Provide biomedical diagnostics capability to facilitate the recognition and treatment of several medical conditions.
    - Address ExMC gap 4.05: Lack of minimally invasive inflight laboratory capabilities with limited consumables required for diagnosing

- Provide analysis capability of biological fluids (i.e. blood, urine, saliva, sweat) in any habitable location

Levels of Care

Level of Care	Mission	Capability
I	*LEO < 8 days	Space Motion Sickness, Basic Life Support, First Aid, Private Audio, Anaphylaxis Response
II	LEO < 30 days	Clinical Diagnostics, Ambulatory Care, Private Video, Private Telemedicine
III	Beyond LEO <30 days	Limited Advanced Life Support
IV	Lunar > 30 days	Medical Imaging, Sustainable Advanced Life Support, Limited Surgical, Dental Care
V	Mars Expedition	Autonomous Advanced Life Support and Ambulatory Care, Basic Surgical Care

*LEO = Low Earth Orbit (e.g. Space Shuttle orbit)

In-Flight Laboratory Analysis

Specifications

- Minimize the equipment's mass, volume, consumables, reagents and power.
- Ease of operation; minimal training.
- Ideally, should have FDA approval, or have gone through the rigors of FDA approval type validation.
- As mission duration lengthens, an analyzer's capability should be readily expanded through software, reagents, dipsticks and/or microfluidic cartridges.
- Short start-up time
- 3- to 5-year shelf life

Functional Requirements

Technology Measurement Capability

Element	Analytes (Examples)	Biological Sample	Technological Approaches
Radiation	**Damage markers** **Genetic, epigenetic traits of individual susceptibility**	**Cell cultures** **Blood** **Blood cells**	**Lab-on-a-chip (LOC)** **Microscopy** **Immunofluorescence (microscopy, flow cytometry)**
Behavioral Health and Performance	Fatigue, stress markers Circadian rhythm markers Depression markers	Blood	LOC biomarker detection
Human Health and Countermeasures	**Bone resorption, metabolism markers** **Ca homeostasis hormones** **Natural Ca isotope composition** **Phosphorus, potassium, magnesium** **Blood cell surface markers, cytokines** **Oxidative stress markers** **Bone metabolism and hormonal regulation markers** **Biomarkers: Physiologic, Metabolic, Oxidative Stress, Cardiovascular**	**Blood** **Urine** **Sweat** **Cell models - *in vitro*** **Cell culture**	**Point-of-care devices** **LOC diagnostics** **Flow cytometry** **Mass spectroscopy** **Colorimetric and fluorimetric microplate analysis** **Biosensors**

Classes of Research Measurements

Analyte Class	Examples
Ions (Na, Cl, etc)	Na, Cl, K,…
Blood Gases	pH, pO_2, pCO_2, BUN,…
Small Molecules	Glucose, lactate,…
Amino acids	3-methylhistidine, GABA,…
Proteins	Il-1, leptin, transferrin, troponin,..
Peptides	BNP, helical peptide P, insulin…
Enzymes	ALT, AST, CK-MB,…
Fatty Acids	Triglycerides,…
Minerals	Fe, Zn, Se, Cu, Mg, P,…
Vitamins	Retinol, b-carotene, folic acid..
Steroids	Cortisol, estradiol, DHEA,…
Lipids	Cholesterol, LDL, HDL,…
Metabolites	Bilirubin, creatinine,…
Cell Type	Leukocyte, WBC, hematocrit,…
Cell Markers	P-selectin, CD4,…

Functional Requirements

Operational Requirements

MEASUREMENTS

Basic Metabolic Panel	Blood Gases Panel	Hematology	Cardiac Panel	Liver/ Renal Panel	Urinalysis
Glucose Calcium Sodium Potassium CO_2, Total Chloride BUN Creatinine	PaO_2 $PaCO_2$ SaO_2 HCO_3 pH	WBC Count RBC Count HCT Hgb Neutrophils Abs. Neutrophils Count Lymphocytes Monocytes Eosinophils PLT	Troponin I CK-MB	Total Bilirubin Direct Bilirubin ALP AST ALT	Specific Gravity pH Leukocytes Nitrites Proteins Glucose Ketones Urobilirubin Bilirubin Blood Urate

Instrument Requirements

- OPERATION
  Start-Up Time - 2 minutes
  Completion of Analysis - give indication
  Self-Calibration
  User - single caregiver or patient (ease of use)
- SHELF-LIFE
  - Storage
  - Cartridge storage up to 3 years at room temperature
- POWER
  - Battery - operate up to 144 hours
  - Switchable power source - external or internal sources

One-Year Evaluation

Expectations

- Perform a multiplexed analysis of whole human blood (demonstrated using serum is acceptable) of the following four analytes:
  - (25 OH) Vitamin-D
  - N-terminal telopeptide (NTx)
  - IFN- γ (interferon gamma)
  - TNF- α (tumor necrosis factor alpha)
- Demonstrate assay performance against a gold standard
- Demonstrate multiplexed assay (4-plex)
- Demonstration at JSC

One-Year Evaluation

Expectations (continued)

Measurement Ranges

- NTx:
  - Adult Male: 5.4-24.2 nM BCE;
  - Premenopausal, Adult Female: 6.2-19.0 nM BCE
- TNFalpha: 0-22 pg/mL
- IFNgamma: 0-5.0 pg/mL
- Vitamin D: 20-150 ng/mL

(BCE – bone collagen equivalents)

Summary

- One-year study objectives align with HRP requirements
- HRP requirements include measurement panels for research and medical operations
  - These measurement panels are distinctly different.
- Instrument requirements are defined
  - Power, volume and mass not quite a critical limitation as for medical operations (deep space exploration missions)
- One-year evaluation goals will lead HHC towards in-flight laboratory analysis capability