Human Research Program

Advanced Exercise Concepts (AEC)
Overview

Gail Perusek, Project Manager
Beth Lewandowski, Marsha Nall, Peter Norsk,
Rick Linnehan, David Baumann

February 10, 2015
Human Research Program Investigator’s Workshop
The current ISS suite of exercise countermeasures hardware is a vast improvement over previous generations of equipment, however vehicle constraints for future exploration missions beyond LEO will not be able to accommodate the size and mass of these ISS-class devices.
The current ISS suite of exercise countermeasures hardware is a vast improvement over previous generations of equipment, however vehicle constraints for future exploration missions beyond LEO will not be able to accommodate the size and mass of these ISS-class devices.

Smaller but similarly capable exploration-class exercise devices will be required to support exploration-class exercise countermeasures regimens and functional performance requirements of the crew.

The Human Research Program (HRP) is managing AEC requirements development and candidate technology maturation for all DRMs from MPCV EM-2 (up to 21 day) to Mars Transit (up to 1000 day) missions.

---

Multi Purpose Crew Vehicle
Exploration Mission EM-2

Asteroid

Mars Transit Vehicle
Exercise Countermeasures

Research

Operations
Advanced Exercise Concepts Scope / Authority

AEC Scope

- **Oversee development** of candidate next generation exercise countermeasures hardware concepts that meet requirements for astronaut health and performance during long duration space missions
- Oversee device Requirements development for candidate systems evaluation (ground and flight)
  - Interpret Astronaut Strength Conditioning and Rehabilitation (ASCR), Exercise Portfolio (EPPf), Bone, Muscle, Sensorimotor, Behavioral Health research findings & inputs and translate to functional requirements for exercise countermeasures systems for all DRMs
- Perform **Market Surveys and Trade Studies** for current and state-of-the-art technologies
- Manage directed work and solicit technologies through NRAs, SBIRs, Innovation Crowd Sourcing Platforms
- Actively seek and fund **Lessons Learned** from relevant areas including CMS Ops
- Conduct and support **Technology Downselects** and provide recommendations to Human Health Countermeasures (HHC) element management
- Manage development of exercise concepts through TRL 6/7 (ground evaluation/flight validation) demonstrating efficacy and hand over to Programs (e.g., MPCV, ISSP) for subsequent flight development and operations

- Authority is captured in the Human Research Program Plan (HRP 47051C), and Human Research Program Requirements Document (HRP 47052E)
### AEC – Multi-Purpose Crew Vehicle (MPCV) and Mars Transit Device Target Performance

**ARED – Advanced Resistive Exercise Device**

**ISS Flight - Operational**

**MPCV**

**Mars Transit Vehicle**

<table>
<thead>
<tr>
<th>Device / DRM</th>
<th>ARED/ISS-1 year</th>
<th>MPCV - 21 days</th>
<th>Mars – 1000 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>~1200 lbm</td>
<td>20 lbm</td>
<td>~120 lbm</td>
</tr>
<tr>
<td>Resistive Load</td>
<td>600 lbf</td>
<td>400 lbf</td>
<td>600 lbf</td>
</tr>
<tr>
<td>Eccentric Load ?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Aerobic ?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
AEC – Multi-Purpose Crew Vehicle (MPCV) and Mars Transit Device Technology Maturation

MPCV EM-2 Mission 2021 and beyond LEO

Cis-Lunar and beyond LEO

Mars Transit Vehicle

Requirements

MPCV Device Summary and Trade Study Recommendations

MPCV Downselect Process

Mars Transit Device Summary and Trade Study Recommendations

Requirements

NASA SBIRs

Direct Funded Development

Exercise Industry

Agency Repurposed Systems

Bio-Inspired Systems

Device for Aerobic and Resistive Training (DART)

Miniature Exercise Device (MED2)

Resistive Overload Combined with Kinetic Yo-Yo (ROCKY)

Orion Flywheel

Next Generation Resistive Exercise Device (NGRED)

Hybrid Ultimate Lifting Kit (HULK)

Multi-Mode Exercise Device (M-MED)

NASA SBIRs

Direct Funded Development

Exercise Industry

Agency Repurposed Systems

MPCV Downselect Process

Mars Transit Downselect Process

MPCV EM-2 Mission 2021 and beyond LEO

Cis-Lunar and beyond LEO

Mars Transit Vehicle

Requirements

MPCV Device Summary and Trade Study Recommendations

MPCV Downselect Process

Mars Transit Device Summary and Trade Study Recommendations

Requirements

NASA SBIRs

Direct Funded Development

Exercise Industry

Agency Repurposed Systems

Bio-Inspired Systems

Device for Aerobic and Resistive Training (DART)

Miniature Exercise Device (MED2)

Resistive Overload Combined with Kinetic Yo-Yo (ROCKY)

Orion Flywheel

Next Generation Resistive Exercise Device (NGRED)

Hybrid Ultimate Lifting Kit (HULK)

Multi-Mode Exercise Device (M-MED)
## Project Milestones

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MPCV Milestones</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EM-2 Delta PDR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EM-1 CDR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EM-2 DDTE Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EM-2 PDR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EM-2 CDR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flight Hardware Development (MPCV funded)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Exercise Hardware Milestones** |
| Preliminary Requirements | Requirements Baseline | Critical Task Study |
| Technology Maturation | Human Evaluations | Prototype H/W Build/Testing |
| Reliability and Human Efficacy Testing |

**Downselect**

HRP / EPPf Contribution

HRP/AEC

HRP/AEC Mars Transit

- **Requirements Baseline**
- **Technology 1 Maturation**
- **Reliability and Human Efficacy Testing**

- **Technology 2 Maturation**
- **Reliability and Human Efficacy Testing**

- **Technology 3 Maturation**
- **Reliability and Human Efficacy Testing**
AEC Highlights from the Past Year

Parabolic Flight Testing of MED-2
ISS Program JSC/ER MED-2 Project

Parabolic Flight Testing with HULK
Motion capture Operational Volume Assessment for MPCV

SBIR/Aurora’s Enhanced Dynamic Load Sensor w/ER Force Shoes on HULK platform

Improved Rowing Modality
Flight #1

Parabolic Flight Testing with HULK
Rowing Exercise

Parabolic Flight Testing with HULK
Squat Exercise
AEC Highlights from the Past Year

**Four Exercise Devices Evaluated for EM-2**

Between October 7 and December 12, 2015, HRP and the JSC Exercise Countermeasures Laboratory evaluated four exercise device concepts for the Orion Exploration Mission (EM-2). The four devices were each evaluated by 10 subjects, totaling 40 individual exercise test sessions over the two months. These human-in-the-loop evaluations will be major criteria for the downselect which will occur in mid-February 2016. The four devices evaluated include:  
- Miniature Exercise Device 2 (MED2) developed by JSC Engineering Directorate, Wyle Flywheel developed by Wyle Laboratories and the JSC Human Health Performance Directorate, Resistive Overload Combined with Kinetic Yo-Yo (ROCKY) developed by Zin Technologies at the Glenn Research Center, and Device for Aerobic and Resistive Training (DART) which was funded by the SDRP Program.

**Human in the Loop Testing for MPCV Downselect**

**Orion Egress Testing in Neutral Buoyancy Lab**

**DART - TDA Research**

**Orion Flywheel - Wyle**

**ROCKY – Zin Technologies**

**MED-2 – JSC/ER**
AEC Highlights from the Past Year

**Computer-Controlled Force Generator**

*Objective*

The primary goal of this work was to incorporate rowing functionality into the Next Generation Resistive Exercise Device (NGRED).

- Provides a resistive load from 5 lb to 600 lb
- Allows a variable speed of 3.1 m/s
- Includes barbell and single-cable interfaces
- Automatically adjusts to the user’s range of motion

In this project, we updated the software with a rowing algorithm to simulate a commercial rower.

We developed a quick release attachment for the NGRED to function as a rower in parallel contract NNX03EC0X.

**Delivery of Phase III Next Generation Resistive Exercise Device**

**2x2015 Class IE Flight MED-2**

SS Program JSC/ER MED-2 Project

**MIT Gravity Loading Countermeasure Skinsuit Testing in Exercise Countermeasures Lab (ECL)**

**Biomechanical Data Collection with Digital Astronaut Project in Exercise Countermeasures Lab (ECL)**
Thank you!
Device Mass and Force Capacity across DRMs

Device Mass (lbm) and Force (lbf)

Pounds

<table>
<thead>
<tr>
<th>Device</th>
<th>Mass</th>
<th>Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARED</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td>DSH</td>
<td>1</td>
<td>600</td>
</tr>
<tr>
<td>MPCV</td>
<td>1</td>
<td>400</td>
</tr>
</tbody>
</table>
Exercise Countermeasures Laboratory (ECL)

- **Capability:** Exercise Countermeasures Lab
  - Ground analog for simulating human-machine-vehicle interface for Vibration Isolation System verification and,
  - Investigator resource for simulating – zero-g, lunar-g, and Martian-g exercise
  - Human in the loop testing of new concepts

T2 Treadmill on ISS

Exercise Countermeasures Lab (ECL)