Space Centrifuge Habitat Design

Space Payload Design
ASEN 5519
Final Presentation

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Centrifuge Applications and Artificial Gravity Generation

- Idea heritage of artificial gravity:
  - Von Braun and Arthur C. Clarke rotating space station concepts
  - Russian Cosmos missions, 1975-'92
  - Small centrifuge on Mir
  - ISS centrifuge (~2008 ?)
  - Mars Society—application to trip to Mars and long term stay

- Ground applications:
  - NASA Ames
  - Astronaut training
  - Other applications—CU Civil Engineering, bio & chem applications, auto industry
A Centrifugal Habitat On Orbit

...Many Experimental Gains

• General goal of centrifuge:
  • To answer “the fundamental question of what role(s) gravity has in the development of organisms from the cellular level up to that of an entire individual organism.” -www.spaceref.com/iss/elements/cam.html
  • “...study the effects of prolonged exposure to Martian gravity on mammals, a vital step on the road to human exploration of Mars.” -Mars Society Translife Website (http://www.marsociety.org/translife/)

• Isolation of gravity level as experimental variable.
• Experimentation at wide range of gravity levels -> test for many scenarios.
...And Many Engineering Challenges

• Angular momentum effects on s/c.
• Safety issues of massive spinning machinery.
• Lifetime issues with spin (e.g. bearing wear, motor life).
• How to get recourses & power to, and waste & data from a spinning test configuration.
• Gravity gradient issues.
• Maintenance of spin rate for consistent “gravity” value.
• Vibration isolation/mitigation onboard s/c; e.g. not to disturb artificial gravity environment or μg environment aboard ISS → Mass Balance Control.
STAGE-1: Student Artificial Gravity Experiment

• An artificial gravity proof of concept and ground control.
• Goal: address key issues in ground prototype -> “Work out the initial bugs.”
  • Smaller scale, smaller budget, quicker timeline.
• Three key issues:
  1. Mass balance and control (MBC) to mitigate vibration transmission.
  2. Spin control/rotating interface.
  3. Habitat (airflow, heat and waste removal, odor control, light, follow National Institutes of Health (NIH) guidelines feasibly).
• In addition:
  • Containment, general sizing of hardware, layout, look and feel of concept all nailed down.
  • Obtain initial data from which to design and build STAGE-2.
  • Use as a ground control for actual on-orbit unit.
STAGE-1

- Intended to be modular with subsystems designed and built in parallel.
**Mass Balance Control & Spin Rate Control**

**Passive MBC:** Bi-directional pivot, aligns hab with net force vector.

**Active MBC:** $\text{H}_2\text{O}$ pumped back and forth based on load cell inputs.

**Spin rate:** Monitored with optical encoder.

**Spin:** Provided with DC motor and adjustable belt.
Habitat “Self-Standing”

- But requires external power, water and air; plug-in concept.
Final Assembly and Operational Unit

- Together show cohesiveness of design process & satisfy key goals.

Full Assembly

First Spin
STAGE-1: Successful First Generation Hardware

- Needs improvements in second generation.
- What worked: Key centrifuge issues addressed successfully
  - Spinning interface.
  - Habitat: airflow, heat removal, food & water availability, waste and odor removal, general viability of a habitat for mice meeting NIH standards.
- What needs improvement:
  - Power system and instrumentation: improve overall system and make a greater part of integrated design from beginning.
  - MBC: concept good, needs refinement, reduce overshoot in feedback.
  - Habitat: improve and automate waste roller, improve change-out access for odor removal.
  - In general: refine systems, instrument well, improve power and data acquisition system (DAQ), take lots of data.
Take Home Lessons Learned From STAGE-1

- Successful proof of concept/hardware demonstration and ground control unit are big steps for the first generation.

- But, refinement to STAGE-2 and going from “flight qualifiable” to “space rated” is a time consuming, detailed process, especially for a manned s/c. (one of reasons for doing ground prototype first).

- Carry parallel design philosophy through to end:
  - Power/DAQ/software lagged behind hardware. Try to keep comparable, integrated pace with one another.
References

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