CubeSat Mechanisms Workgroup

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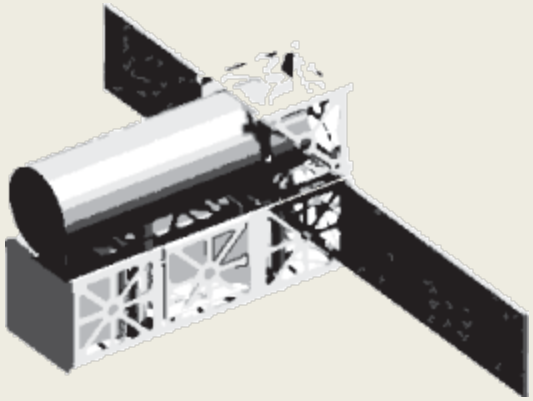


Overview:

- What are common spacecraft mechanisms?
- When should they be used?
- CubeSat Mechanisms Workgroup
- Lessons Learned
- Component Development: ARTS

Mechanisms:
They have to move, just not before 9am

Vanguard 1 - 1958

Booms & Antennas

GRAB- 1960

Tethers

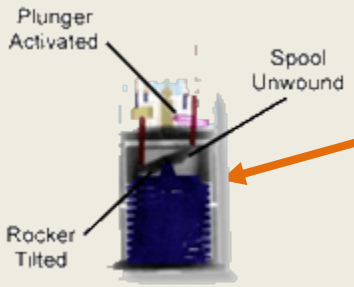
TiPS

Deployable Arrays
or Radiator

Clementine

Solar Array Drives
Hinges

Release
Devices



Non-Explosive Sep Nut

Mechanisms in Space

First question you should hear from any mechanisms engineer:
Do you *really* need a mechanism? It is going to cost you time, money, schedule, and risk!!

Galileo: Courtesy JPL/NASA

Mechanisms are one of the riskiest subsystems and should only be used when necessary. "Moving parts are the spacecraft engineer's nightmare"[1]

Mechanisms do enable missions that could not otherwise happen. Moore's Law has reduced the size of electronics components, but hasn't touched the laws of physics. "Big" space has had tremendous success with deployable antennas, arrays, and booms.

$$\Delta\theta = \frac{\lambda}{D}$$

$$G_t = \left(\frac{\pi d}{\lambda}\right)^2 \eta$$

[1] *"Space Systems Failures: Disasters and Rescues of Satellites, Rocketer, and Space Probes", David Harland and Ralph Lorenz, Praxis, 2005*

Mechanisms in CubeSats

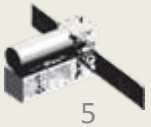
- Examples
  - Burn wire release devices
  - Whip antennas
  - Carpenter tape hinges
  - Deployable arrays
  - Tethers
  - Reaction wheels
  - Control Moment Gyros
- Role in CubeSats will only grow as missions increase in capability
- Largely custom – single mission designs
- Typically designed by young, innovative work force
- Lessons learned not shared (internally or externally)
- New class of mechanisms
- Difficult to find if someone has previously built a mechanism to your needs

What is the solution?
CubeSat Mechanisms Workgroup

A CubeSat Mechanisms Workgroup (CMW) provides the connectivity and workspace to share the resources and lessons learned from big and small space. Spacecraft mechanisms are an extremely niche field. Community resources (textbooks, classes, conferences etc.) are rare.

Goals for the CMW

- **Prevent On Orbit Failures**
- Create a running list of CubeSat mechanisms and developers
- Facilitate sharing lessons learned in development of current mechanisms
- Provide a means for non-mechanisms engineers find people or solutions
- Sustain level of knowledge with young, rapidly changing workforce
- Introduce CubeSat Mechanisms to “big space” community
- Begin submitting papers to ESMATS and AMS conferences and increase attendance



Top Mechanisms Resources

Conferences Alternate Between US and Europe

Sept. 2009, European Space Mechanisms and Tribology: Vienna, Austria
http://www.esmats.eu/

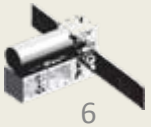
Sept. 2010 Aerospace Mechanisms Symposium: Cape Canaveral, FL
https://www.aeromechanisms.com/ (43 years of mechanisms)

Book

"Space Vehicle Mechanisms: Elements of Successful Design", Peter Conley

Short Course – 3 Days

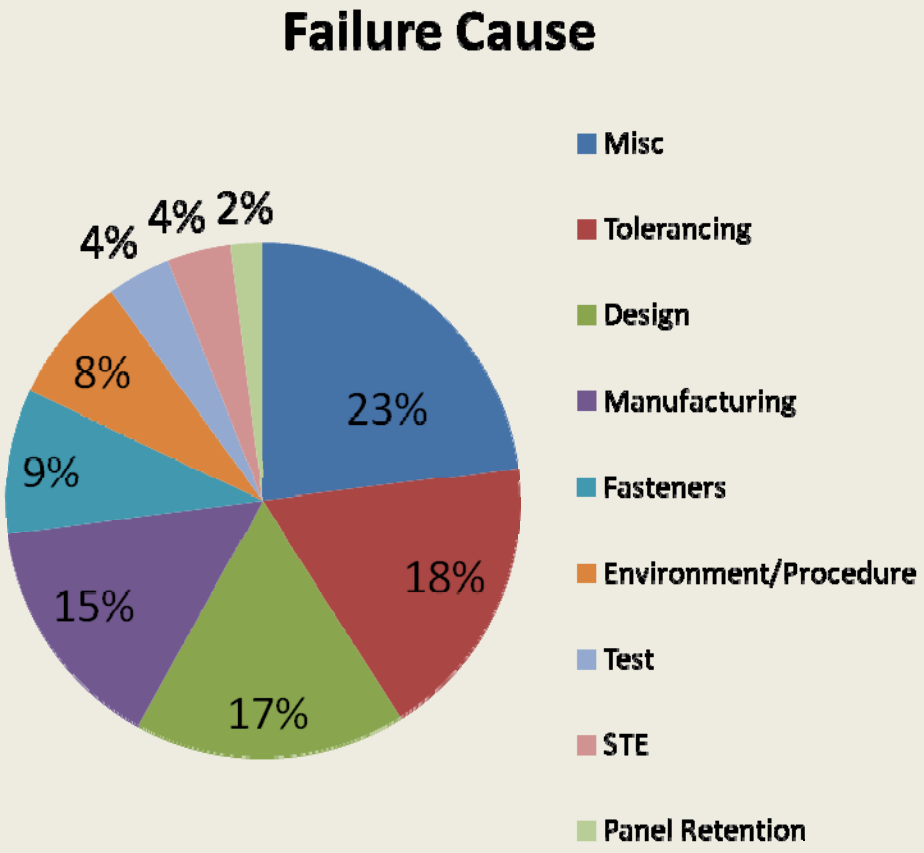
Space Vehicle Mechanisms: Elements of Successful Design
Bill Purdy, http://www.launchspace.com/1135.html



Example AMS Paper: ISS Mechanism Failures

350+ ISS ground & on-orbit structures and mechanisms problems from 2000 through 2004 were documented and analyzed for cause.

Recent Anomalies
- Solar Array Drives
- Solar Array Deployment
- Water Recycling Centrifuge



"Review of International Space Station Mechanical System Anomalies", David S. McCann 37th AMS Proceedings, Johnson Space Center, 2004

Lessons Learned: Test, Test, Test

"Test how you Fly, Fly how you test"

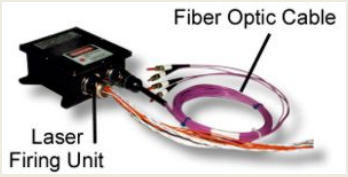
- CubeSat mechanisms do not have the benefit of 100,000's users finding problems
- Testing catches all of the things you forgot about
- Testing of early designs must be factored into the schedule
- Each test is not only a test of your mechanism, but also of your test setup
- Testing is required for thermal or structural stiffness modeling

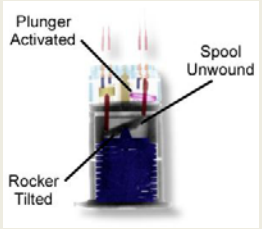
Key CubeSat Mechanisms Needed

- Release Devices
  - Fast acting variation
  - Rigid joints
  - Insensitive to application
  - Insensitive to user integration
  - Low power, volume
  - Few parts
  - Works over large voltage ranges
- Deployable Articulating Arrays
  - Adjustable hard stop positions
  - Latching option
  - Ability to autonomously track the sun
  - Redundant sliding surfaces
- Deployable Antennas
- Your Ideas

Advanced Release Technologies (ARTS) Program

- NRL Program in 90's
  - Develop lighter and less expensive spacecraft release devices
  - Lower shock devices
  - Majority of devices before ARTS were explosive (bolts, nuts, cutters, etc.)
  - 4 devices were tested on the first flight spacecraft
- Two Phases
  - Development and Evaluation
  - Qualification and Flight
    - Down select to "best" technologies
    - Two of each release device flown





Lessons Learned from ARTS[1]

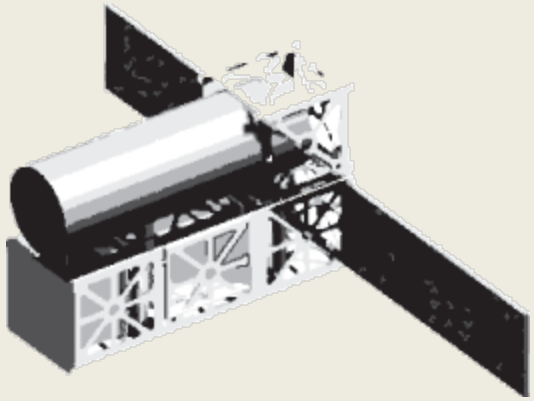
- Flight experiments
  - Forced developers to address all issues effecting component design (interfaces, safety, etc.)
  - Staking reputation on a device working is an excellent driver
- High voltage swings are difficult to accommodate for heat-actuated mechanisms
- Need for a common qualification standard
- Good joint design and installation procedures were important to reliability
- Verified reduced cost with non-explosive actuators

[1] *"Advanced Release Technologies Program", Bill Purdy, 28th Aerospace Mechanisms Symposium, May18-20, 1994*

Next Steps for the CubeSat Mechanisms Working Group

- Contact me if interested in participating or assisting in the organization of the workgroup

  [poppenheimer@space.nrl.navy.mil]
- Provide feedback on mechanisms or capabilities needed
- Begin documenting mechanisms and writing papers for AMS conference
- Look for more information at Small Satellite Conference and via email



Questions?

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