RadSat

Chronicles of Student Built Satellites at Montana State

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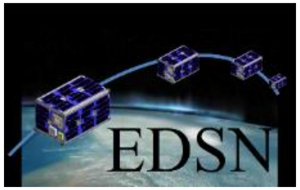
MONTANA STATE UNIVERSITY
NORM ASBJORNSON College of ENGINEERING

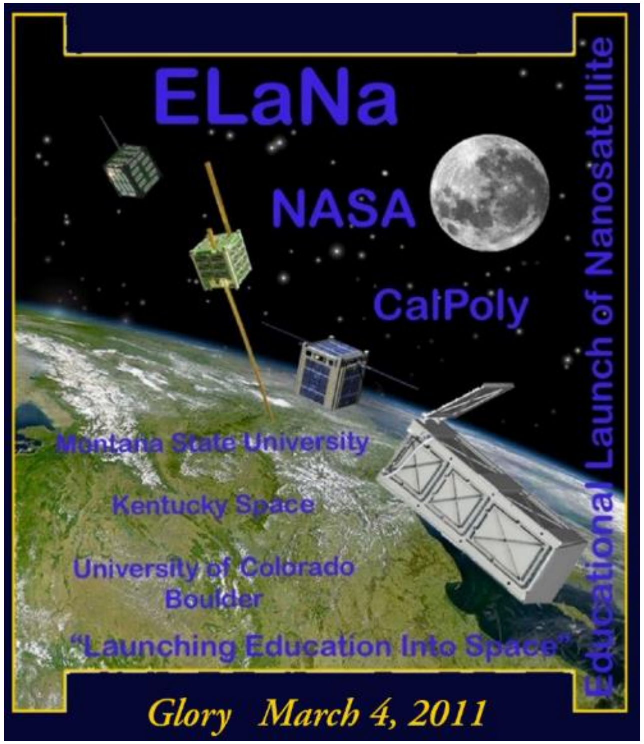
MSGC

Quick Background of MSU

Space Science & Engineering Lab

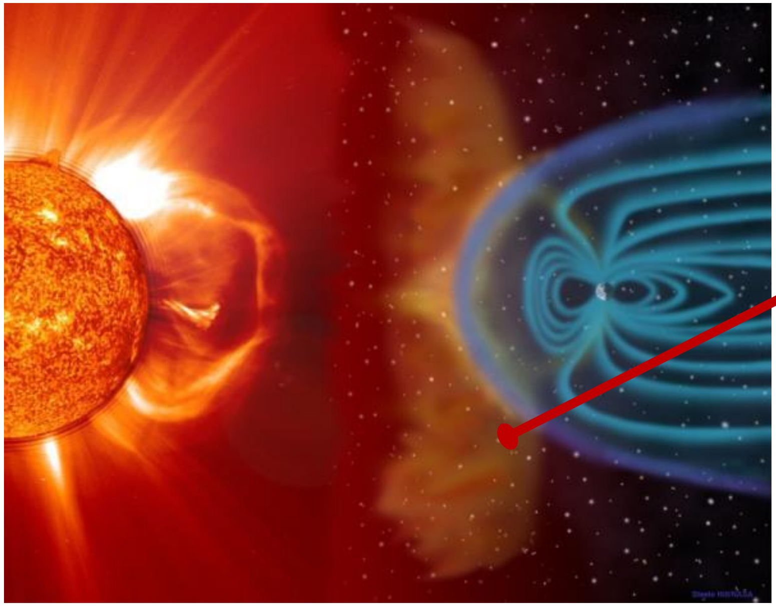
- Founded in 2000 with support from MSGC.
- Provides students hands-on experience w/ real space missions.
- One of the first universities to engage in small satellites (part of the inaugural ELaNa-I).
- Has sent 9 small satellites into space (10 & 11 within next 6 months.)





Demonstrate a Radiation Tolerance Strategy for Computers

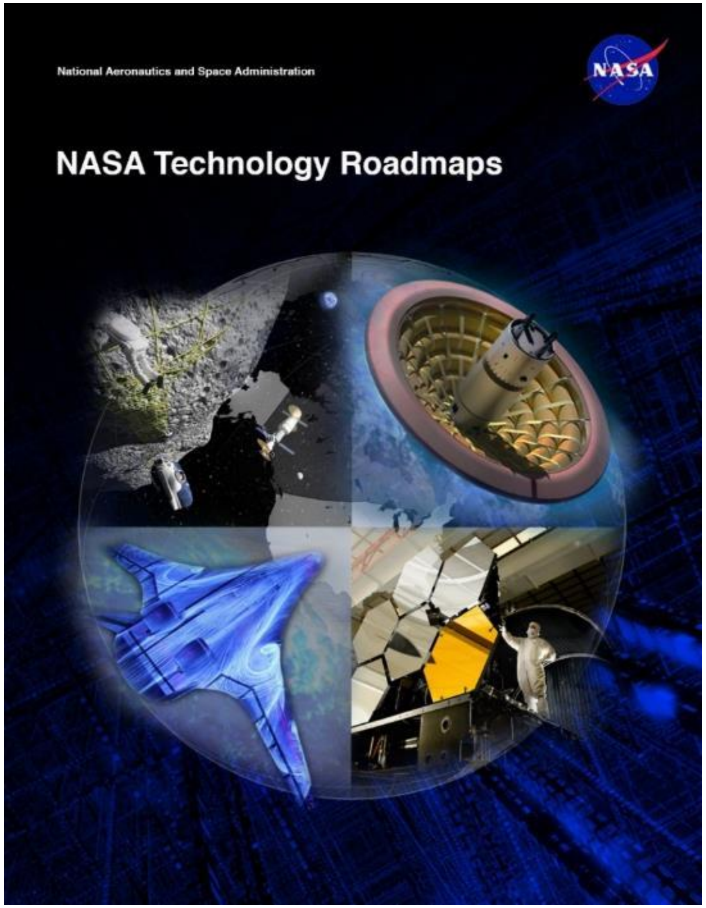
- Reconfigurable/redundant architecture.
- Build on COTS parts.
  - ❑ *Low cost*
  - ❑ *High performance*
  - ❑ *Low Power*



Why Do This Research?

Space Computing Needs

- NASA Technology Area 11 – Flight Computing
  - *Increased Computation*
  - *Radiation hardened technologies*
  - *Low power requirements*
- Can our technology meet the needs of future missions?



Small Satellites

- Typically use non-radiation hardened parts.
- Are taking on longer and more meaningful missions.
- Can our technology provide computation and reliability at a price point suitable for SmallSats?

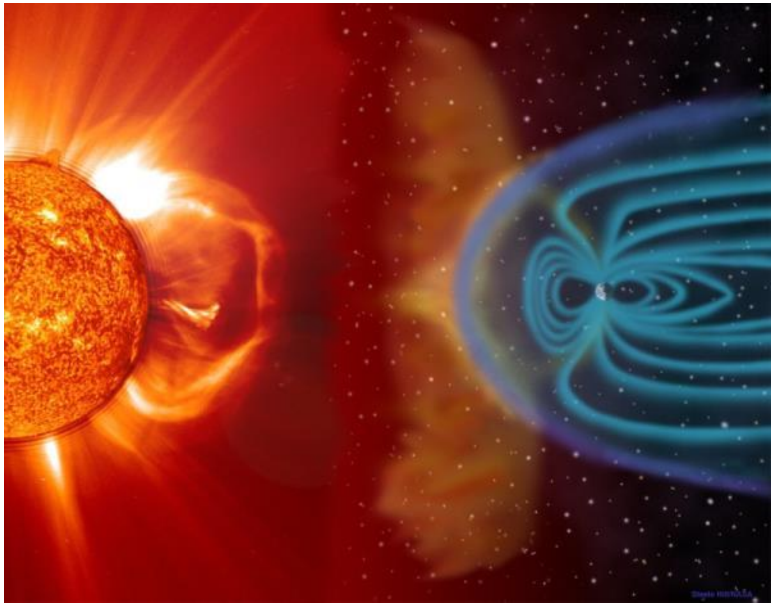
Reconfigurability = Cost & Performance

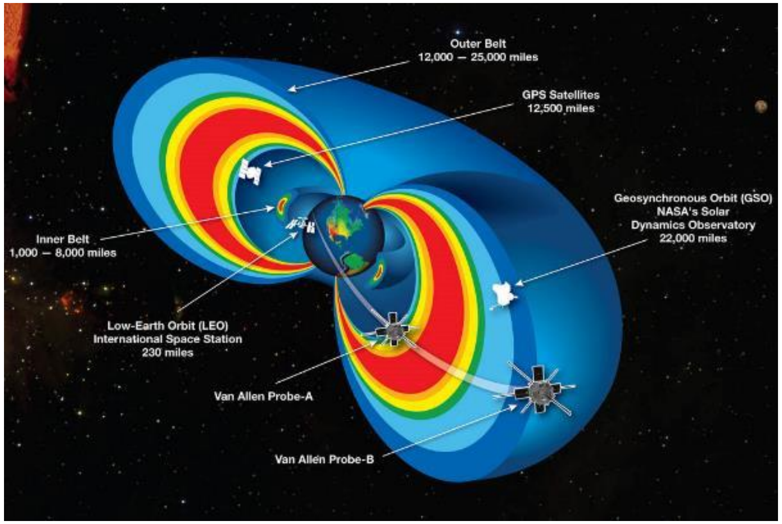
- Reusing hardware reduces mass
- Real-time updating of hardware optimizes for task at hand.

Why Not Just Fly COTS Computers?

Space is Harsh

Earth is Protected

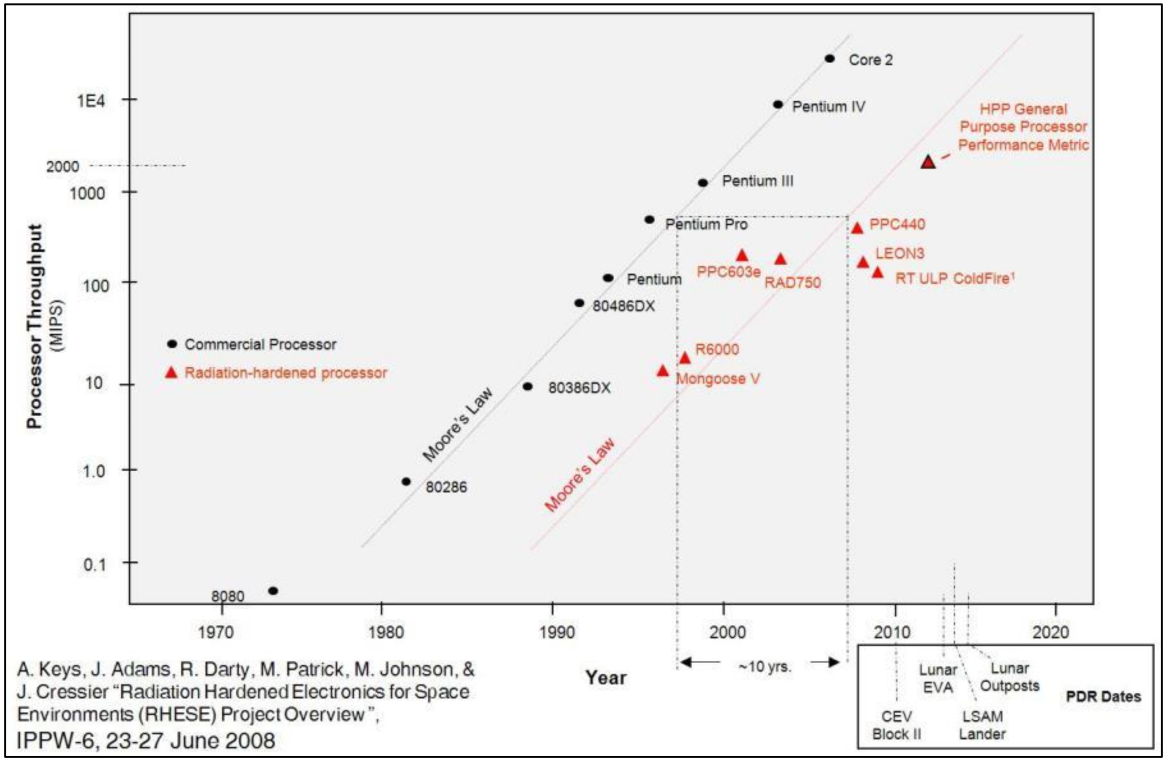




Particle Type	Energy Range
Trapped protons and electrons	≤ 100 MeV
Alpha particles	5 MeV
Solar protons	≤ 1 GeV
Cosmic rays	≥ 1 GeV

The Issue with Existing Techniques

- The unique processing techniques lowers the volume, which increases **cost**.
- The unique processing techniques reduces the **performance**.



- Rad-Hardened Processers lag in performance to their commercial counterparts by ~10 years

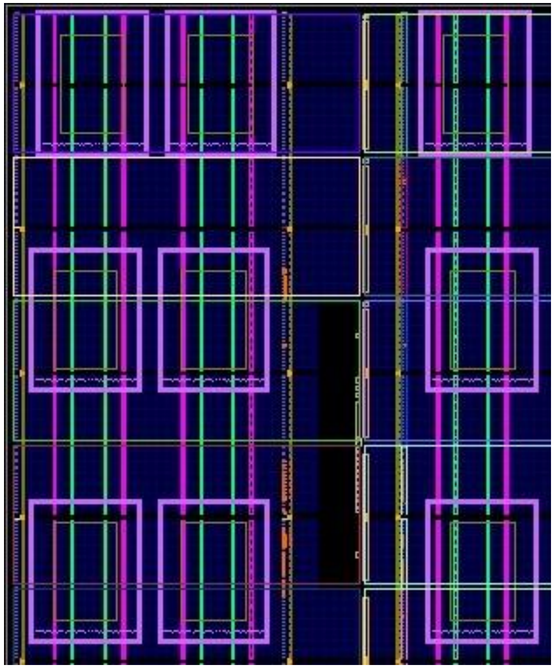
Fault Tolerance Through Abundant Spares

1. **Use <65nm process node to achieve TID tolerance.**

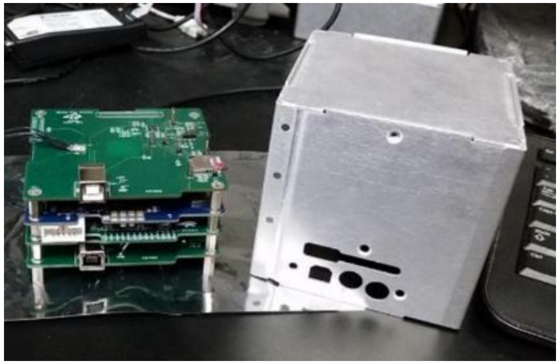
2. **Triple Modular Redundancy + Spares**
   - 3 Tiles run in TMR with the rest reserved as spares

3. **Spatial Avoidance and Background Repair**
   - If TMR detects a fault, the damaged tile is replaced with a spare and foreground operation continues
   - The tile is "repaired" in the background via **partial reconfiguration (PR).**

4. **Scrubbing**
   - Blind scrubbing continually runs through tiles (fast)
   - Readback scrubbing periodically runs through rest of fabric (slower)



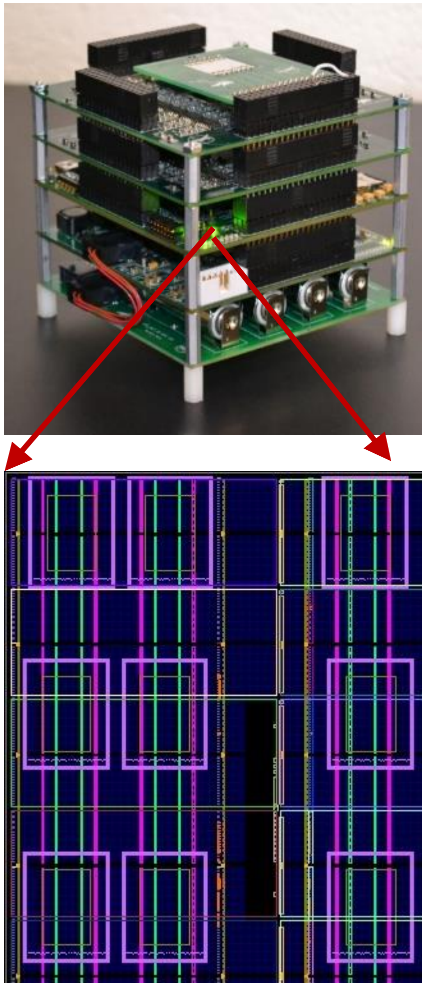
FPGA Floor Plan

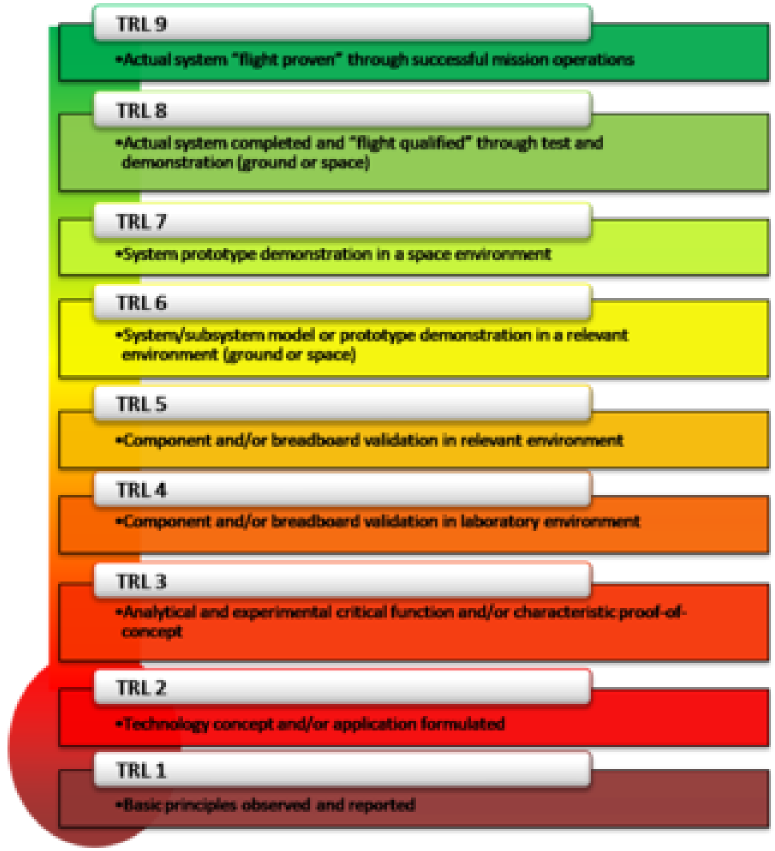


Build as a SmallSat Computer

Ok, Now Test It…

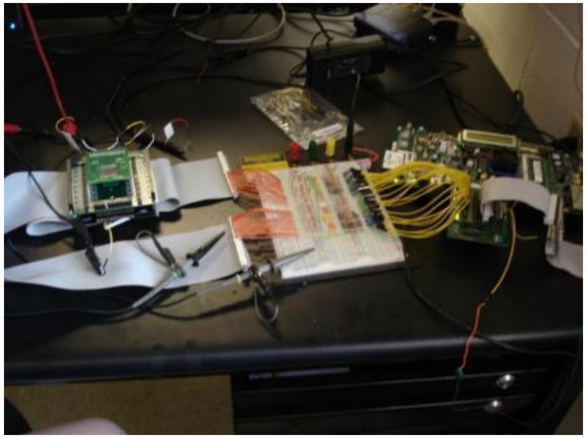
Technical Readiness Level (TRL)

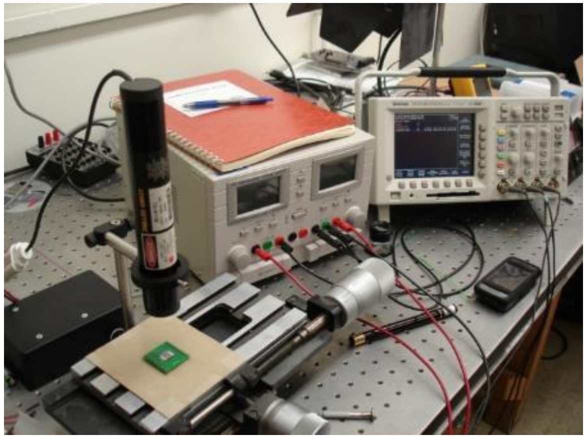




Step 1 – Build a Prototype to See if it is Possible

- The **Montana Space Grant Consortium** funds an investigation into conducting radiation tolerant computing research at MSU. The goal is to understand the problem, propose a solution, and build relationships with scientists at NASA.





Clint Gauer (MSEE from MSU 2009) demo's computer to MSFC Chief of Technology Andrew Keys

Timeline of Activity at MSU

MSGC Proof of Concept

(2008-2010)

2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014-16 | 2016 | 2017-20

Technical Readiness Level (TRL-3)

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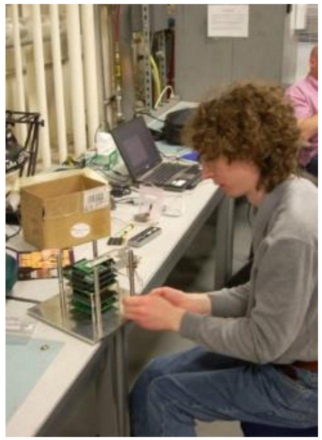
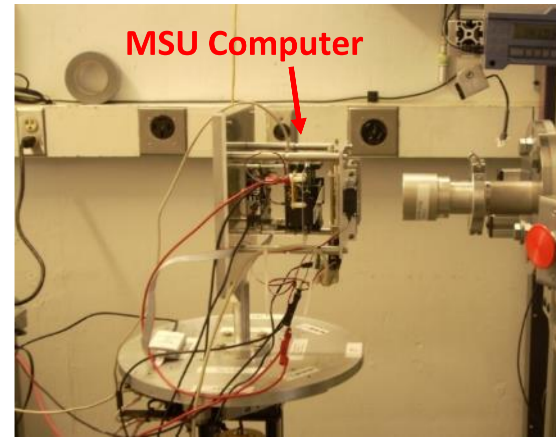
Step 2 –Test in a Cyclotron

- **<u>NASA EPSCoR</u>** funds the development of a more functional prototype and testing under bombardment by radiation at the Texas A&M Radiation Effects Facility.



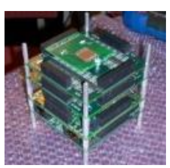
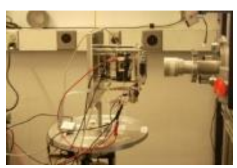
Ray Weber (Ph.D., EE from MSU, 2014) prepares experiment.

Timeline of Activity at MSU

Proof of Concept

(2008-2010)

Prototype Development & Cyclotron Testing

(2010-2012)

2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014-16 | 2016 | 2017-20

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Step 3 – Demonstrate as Flight Hardware on High Altitude Balloons

- **<u>NASA Education Office</u>** funds the development of the computer into flight hardware for demonstration on high altitude balloon systems, both in Montana and at NASA.

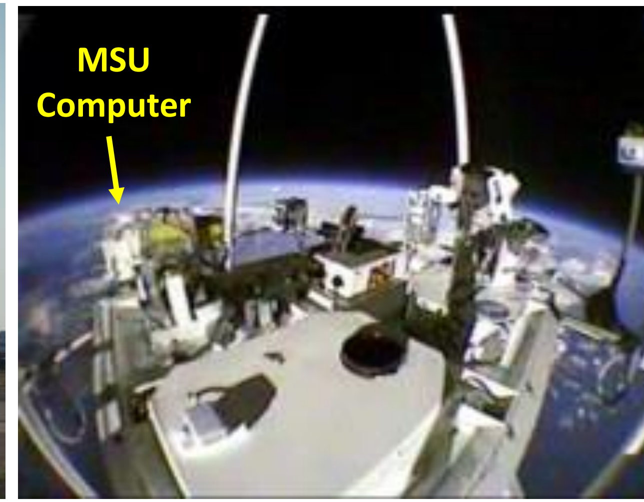
MSU students get NASA experience sending experiments to the edge of space

July 21, 2011 -- Melynda Harrison, MSU News Service

Two groups of students, staff and faculty from Montana State University and the Montana Space Grant Consortium gathered on a plateau overlooking the Yellowstone River east of Livingston on Thursday morning. Some checked the rigging on what looked to be cardboard and Styrofoam boxes--their modest exteriors belying the high tech equipment inside. Other team members filled a giant latex balloon with helium.

The two groups were working on launching their experiments into near-space, 100,000 feet above the Livingston airport runway where the groups met. The hands-on summer projects are giving Montana students an opportunity to engage in real world science and build their resumes.

Members of the Balloon Outreach, Research, Exploration and Landscape Imaging System (BOREALIS) Project, part of the MSGC, sent temperature and pressure sensors, still and video cameras, and a "command center" used to control the release of a parachute and send GPS coordinates, into the sky. Under the direction of Berk Knighton, BOREALIS flight director, the nine undergraduate interns, three from Tribal Colleges, and one high school student, from across Montana, spent 10 weeks designing and building experiments for several balloon flights.



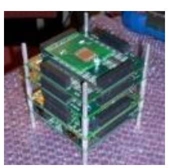
Justin Hogan (Ph.D., EE from MSU, 2014) prepares payload.

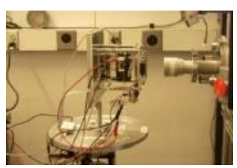
Timeline of Activity at MSU

MSGC — Proof of Concept

(2008-2010)

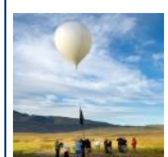
NASA — Prototype Development & Cyclotron Testing





(2010-2012)

NASA — High Altitude Balloon Demos



(2011-2013)

2008 — 2009 — 2010 — 2011 — 2012 — 2013 — 2014-16 — 2016 — 2017-20

Technical Readiness Level (TRL-6)

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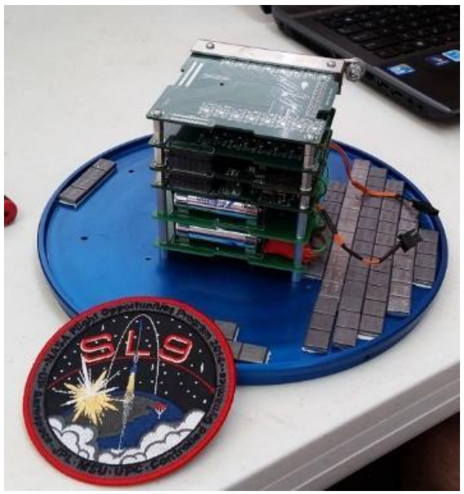
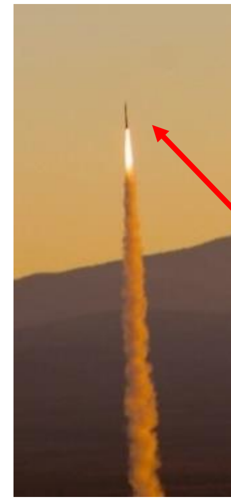
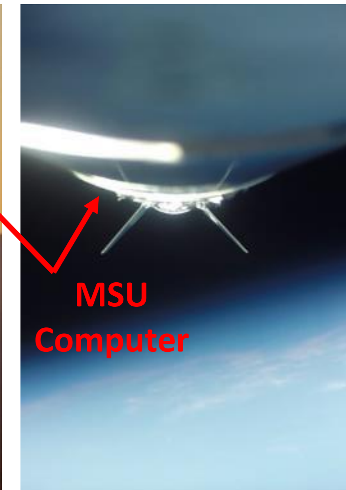
Step 4 – Demonstrate as Flight Hardware on a Sounding Rocket

- **<u>NASA OCT & FOP</u>** fund the demonstration of the computer system on sounding rocket.
- Flew on UP Aerospace SpaceLoft-9 in Oct 2014.





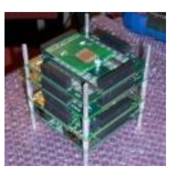


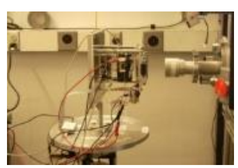
Timeline of Activity at MSU

MSGC — Proof of Concept

(2008-2010)

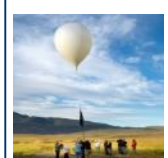
NASA — Prototype Development & Cyclotron Testing





(2010-2012)

NASA — High Altitude Balloon Demos



(2011-2013)

NASA — Sounding Rocket Demo

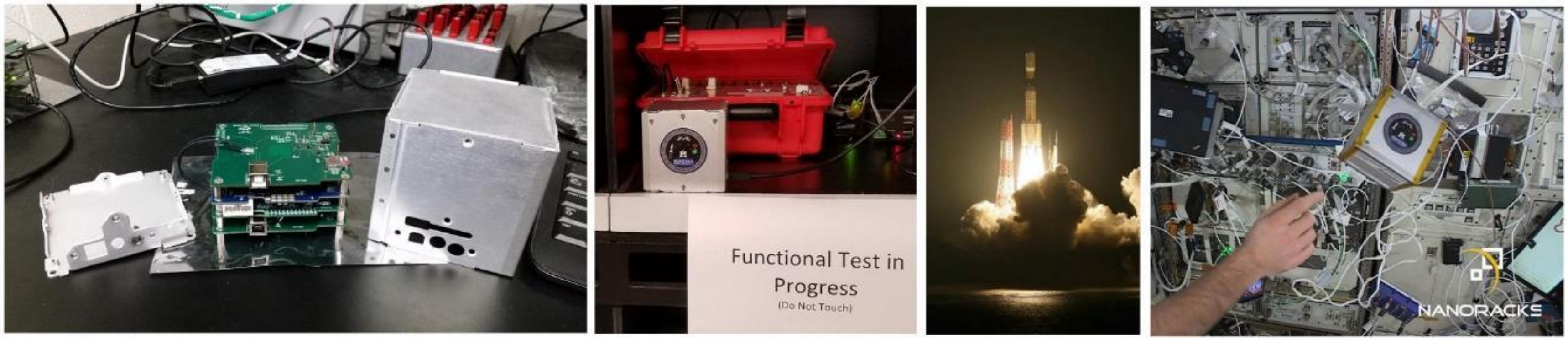
(2012-2016)

2008 — 2009 — 2010 — 2011 — 2012 — 2013 — 2014-16 — 2016 — 2017-20

Step 5 – Demonstrate on the International Space Station

- **NASA EPSCoR** funds the demonstration of computer system on ISS

TRL 7 – System Demonstration in an Operational Environment



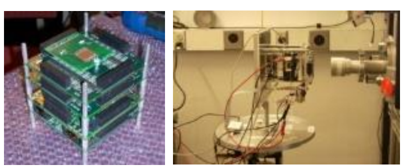
2014-16: Internal ISS Demonstration using NanoRacks CubeLab Experiment Locker (HTV6 Launch).

Timeline of Activity at MSU

MSGC — Proof of Concept

(2008-2010)

NASA — Prototype Development & Cyclotron Testing



(2010-2012)

NASA — High Altitude Balloon Demos

(2011-2013)

NASA — Sounding Rocket Demo

(2012-2016)

NASA — ISS Demo

(2014-2016)

2008 — 2009 — 2010 — 2011 — 2012 — 2013 — 2014-16 — 2016 — 2017-20

Step 6 – Demonstrate as a Stand-Alone Satellite

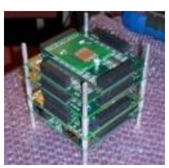
- **NASA SmallSat Technology Partnership Program (SSTP)** funds the planning for a stand-alone satellite demonstration of the computer technology.
- **NASA Undergraduate Student Instrument Program (USIP)** funds a team of undergraduates to build the satellite and prepare for deployment.
- **NASA CubeSat Launch Initiative (CSLI)** selects RadSat-g for launch on ELaNa-23 mission on CRS-OA9.
- **NASA ISS EPSCoR** funds building the flight unit, delivering to the launch provider, and operating the satellite post-deployment.

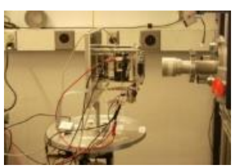
Timeline of Activity at MSU

Proof of Concept

(2008-2010)

Prototype Development & Cyclotron Testing





(2010-2012)

High Altitude Balloon Demos

(2011-2013)

Sounding Rocket Demo

(2012-2016)

ISS Demo

(2014-2016)

Satellite Demo

(2015-2018)

2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014-16 | 2016 | 2017-20

RadSat Mission Concept

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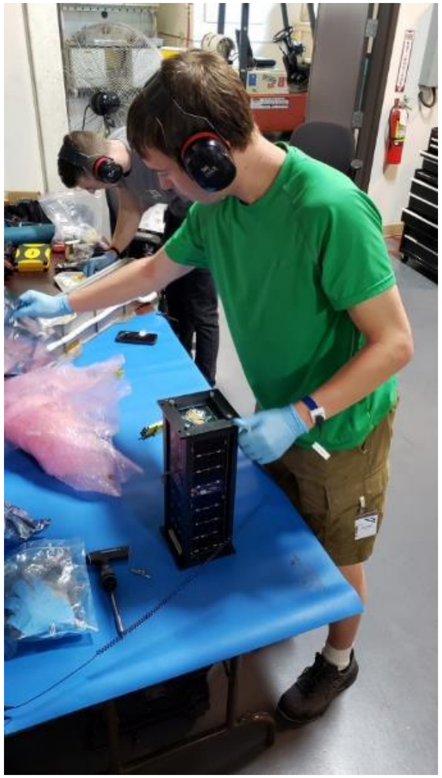
1) Students Build It



RadSat Mission Concept

1) Students Build It
2) Launch it to the International Space Station

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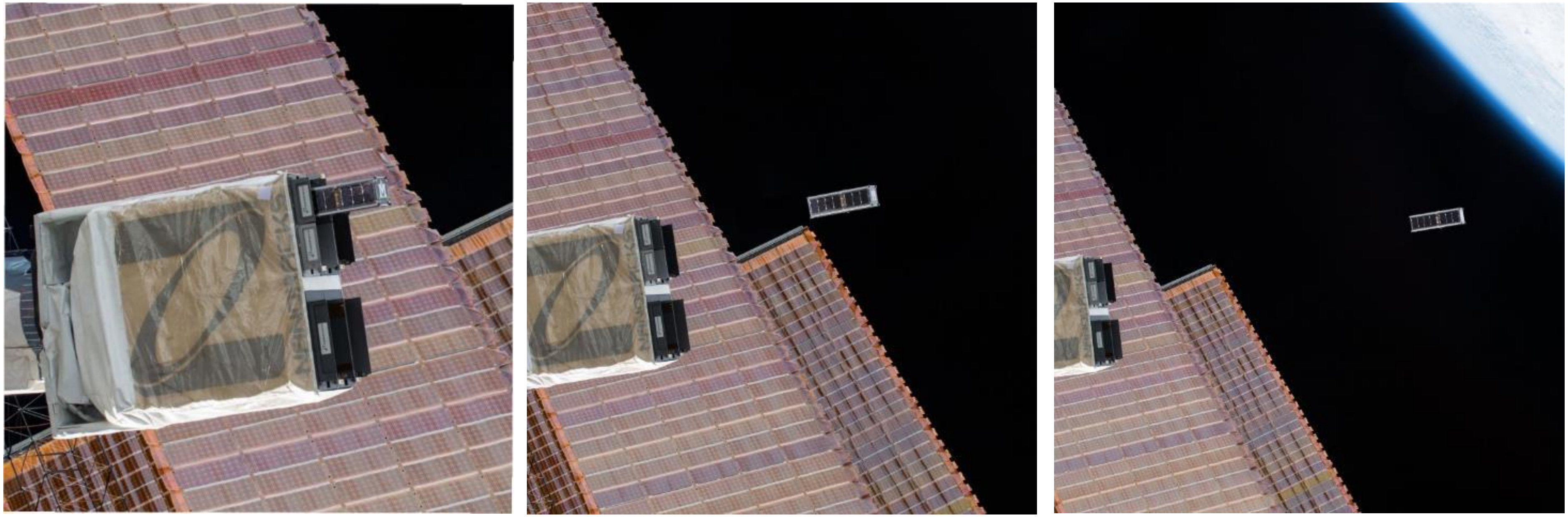
2) Launch it to the International Space Station
3) Put into Orbit using NanoRacks CubeSat Deployer



RadSat Mission Concept

1) **Students Build It**
2) **Launch it to the International Space Station**
3) **Put into Orbit using NanoRacks CubeSat Deployer**
4) **Operate from SSEL Ground Station**

Everything was Designed and Built By MSU Students

Todd Buerkle, Justin Hogan, Ray Weber at Johnson Space Center for demo, 2012.

Todd Buerkle & Jennifer Hane demo computer at Marshall Space Flight Center, 2012.

Clint Gauer at Marshall Space Flight Center for demo, 2009.

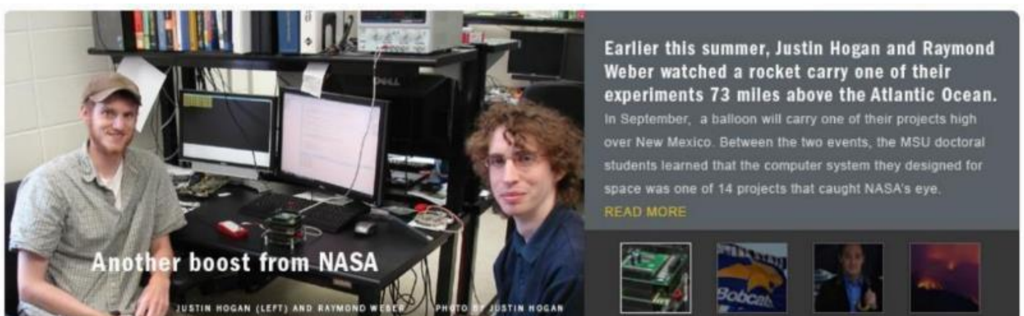
Justin Hogan at the NASA Columbia Scientific Balloon Facility, 2012.

Clint Gauer demo's computer at Marshall Space Flight Center, 2009.

Kaysha Young prepares payload for balloon flight, 2012.

2011 balloon team featured in MSU news story, 2011.

Todd Buerkle, Jennifer Hane at the Marshall Space Flight Center, 2011.



Justin Hogan & Ray Weber featured in MSU News Story, 2012.

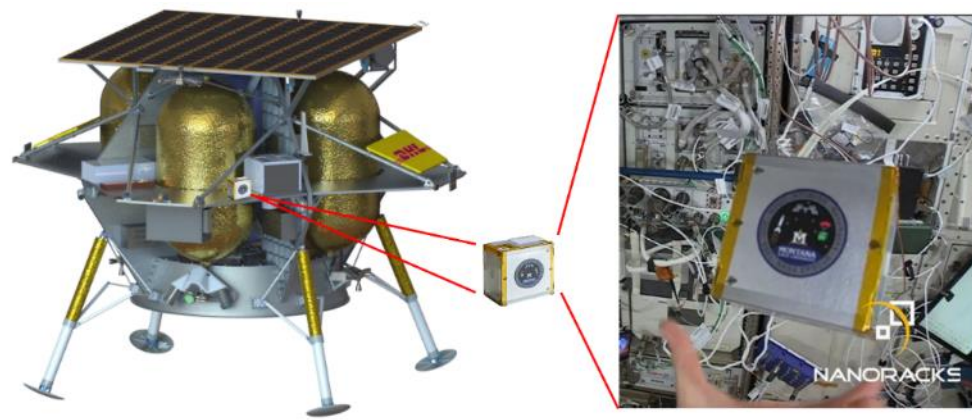
2013 balloon team recovers payload in front of moose, 2013.

July 1, 2019
RELEASE 19-053

NASA Selects 12 New Lunar Science, Technology Investigations

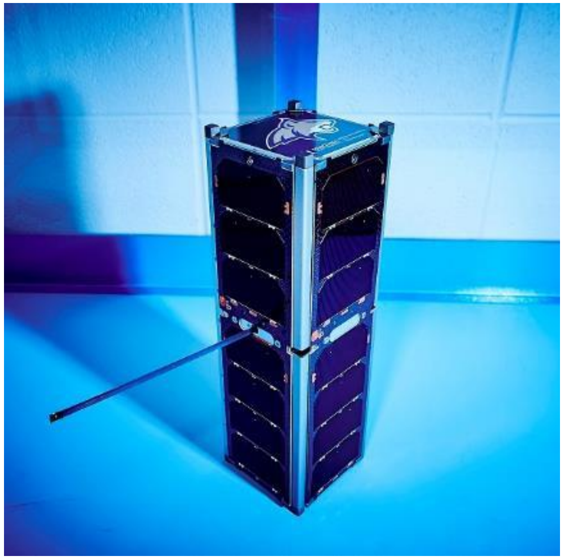
Lunar Demonstration of a Reconfigurable, Radiation Tolerant Computer System.

- Lunar Demonstration of a Reconfigurable, Radiation Tolerant Computer System aims to demonstrate a radiation-tolerant computing technology. Due to the Moon's lack of atmosphere and magnetic field, radiation from the Sun will be a challenge for electronics. This investigation also will characterize the radiation effects on the lunar surface.
- The principal investigator is Brock LaMeres of Montana State University, Bozeman.



The Pros…

- Fantastic experience for students.
- They are HIGHLY recruited.
- High profile for the university.



Professor Reflections

The Pros…

- Fantastic experience for students.
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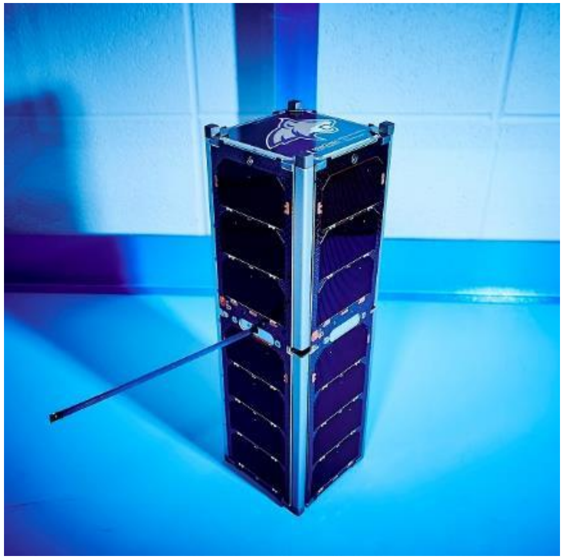
The Cons…

- Graduation kills productivity.
  (the experience often displaces results)
- Keeping funding going is piecemeal and exhausting.
  (The work I showed represents 14 different grants)
- NASA schedules don’t match academic calendars.



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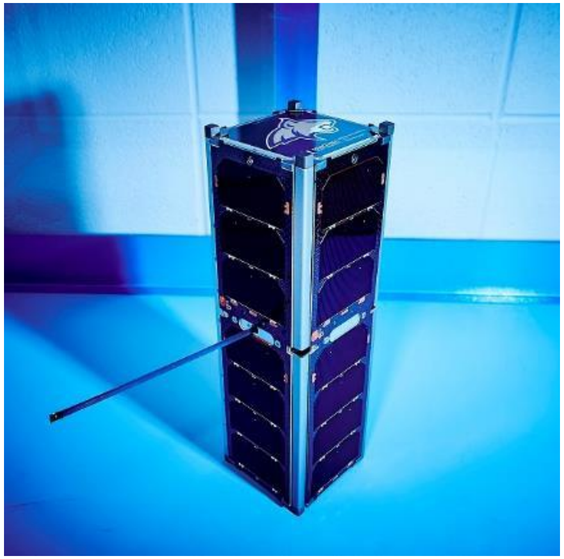

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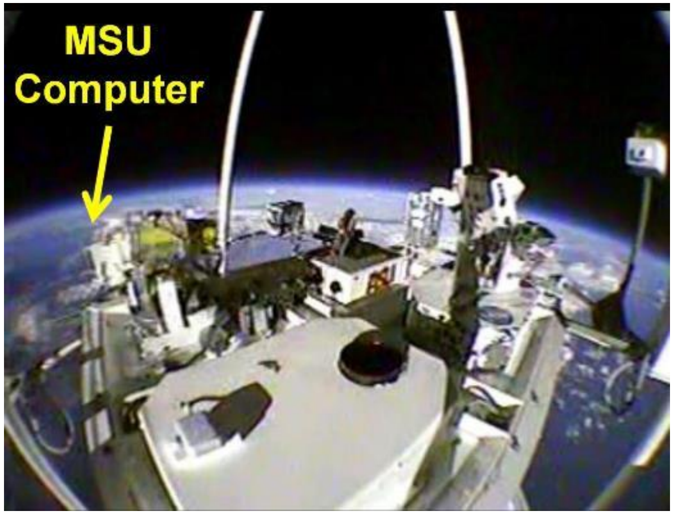
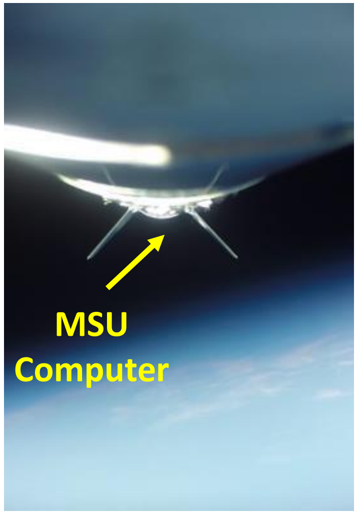
The Box Score

- It's worth it!

Questions


MSU
Computer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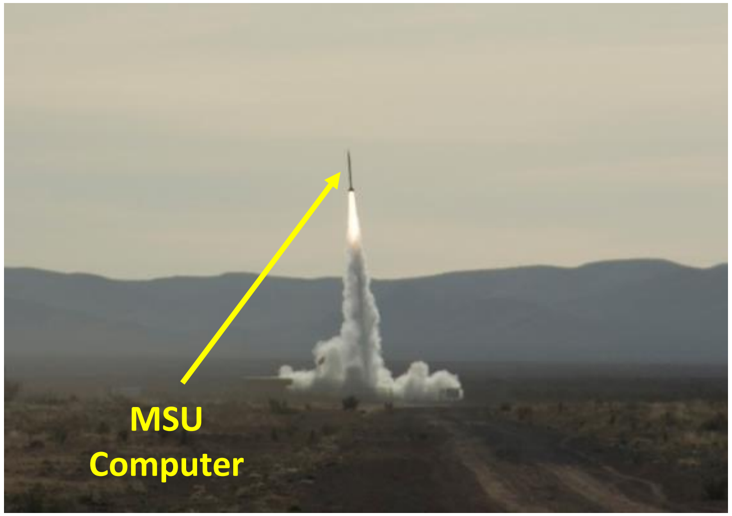
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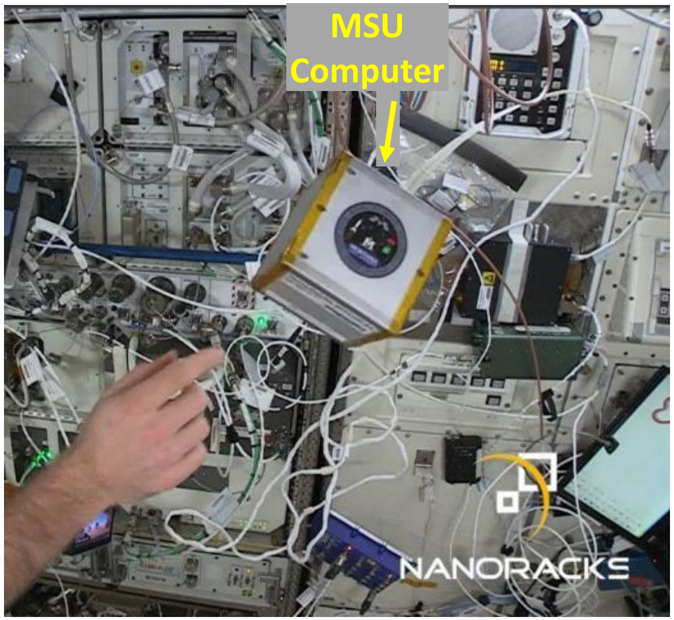
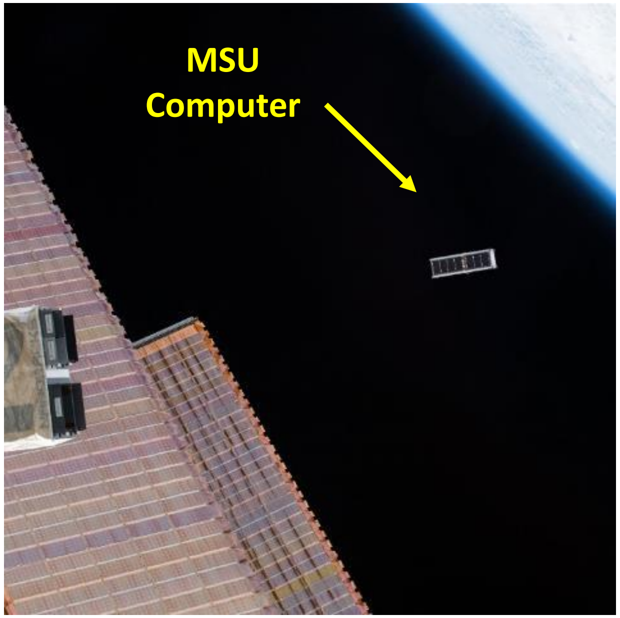

MSU
Computer
NANORACKS


GO CATS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