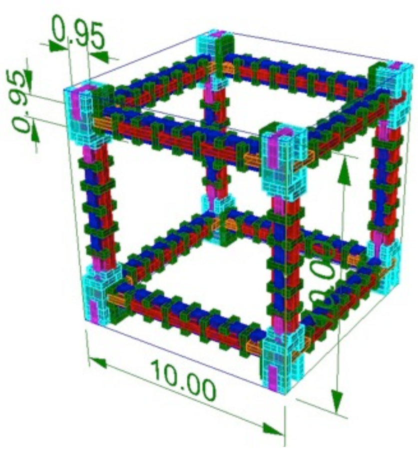
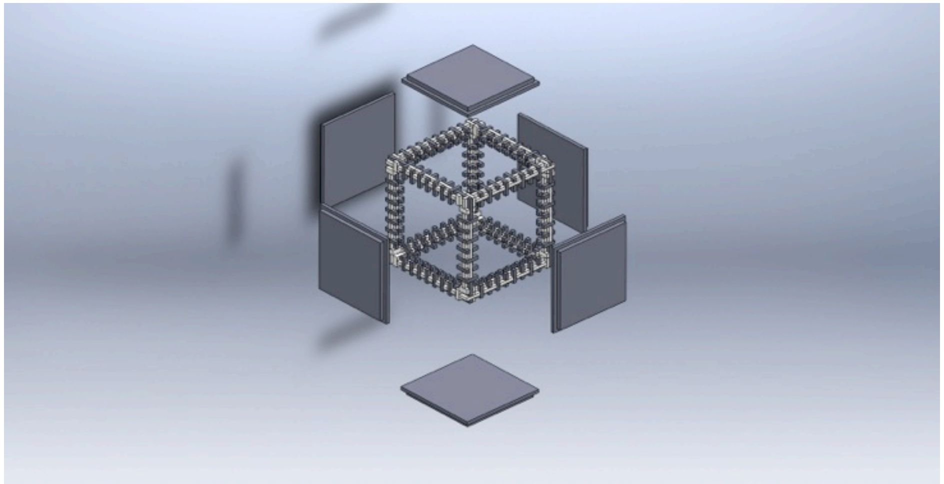
Multi-Purpose Avionics Core Element (M-PACE): Using Advanced Manufacturing to Rapidly Develop CubeSat Subsystems and Components



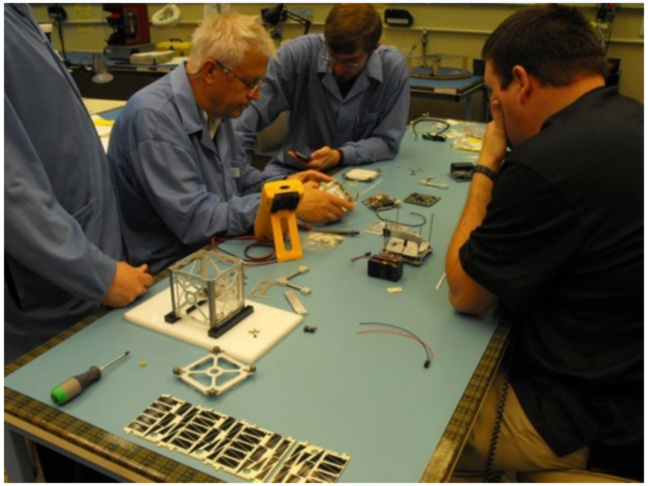


By: Christopher Hartney, Sarah Hovsepian and Zac Manchester

10th Annual CubeSat Developers' Workshop

April 25, 2013

TechEdSat



SMALL SATELLITES

More With Less

Small satellites gaining users as capability and applications increase

Frank Morring, Jr. Washington

Small satellites, once the realm of one-off low-budget science missions and undergraduate engineering classes, have come full circle with the growing realization among hard-pressed, high-end users that the little birds can do the big jobs, too.

The smallest of them—cubesats—are rapidly evolving into an operational commercial, scientific and military technology. Higher up the payload-weight scale, the high cost per pound of launching payloads and the growing skill of spacecraft miniaturizers are making satellites that are small enough to ride as secondary payloads attractive to a variety of customers, particularly if they can be mass-produced or produced rapidly in single units.

The launch-cost consideration may change, as the growing interest in small spacecraft attracts a new generation of small launchers designed to carry them. And the spacecraft themselves are increasingly capable, with government money flowing into the arena in search of a way to do more with less.

"From where we have been 10 years ago to where we are now is a complete 180," says Roland Coelho, a member of the research staff at California Polytechnic State University's engineering school, one of the main U.S. centers for cubesat development. "In the past it's been primarily educational. . . . As we have kind of grown—the entire community worldwide over the past decade—we really have started to see some niche markets where cubesats can play a vital role. It's clearly the most evident in the government cubesat programs that we have today. The government, and particularly the U.S. government, has been the driving force in this technology because that's where all the funding is."

Government interest in small satellites is not limited to cubesats, or even to spacecraft. The U.S. Defense Advanced Research Projects Agency (Darpa) is spending $46 million to find ways to launch satellites weighing up to 100 lb. on 24-hr. notice for less than $1 million (see p. 44). And the Air Force and National Reconnaissance Office consider small satellites a way to lower risk in national security spacecraft by adding redundancy in orbit.

"Even if 20% of them failed, you'd still do your mission, as there's sort of a natural resiliency in using constellations of smaller satellites," says John Roth, whose company—Sierra Nevada

TechEdSat is scheduled to be the first U.S. cubesat deployed from the International Space Station.

For additional photos and the latest on smallsats, check out the digital edition of AW&ST on leading tablets and smartphones, or go to AviationWeek.com/smallsats

AVIATION WEEK & SPACE TECHNOLOGY/JULY 30, 2012

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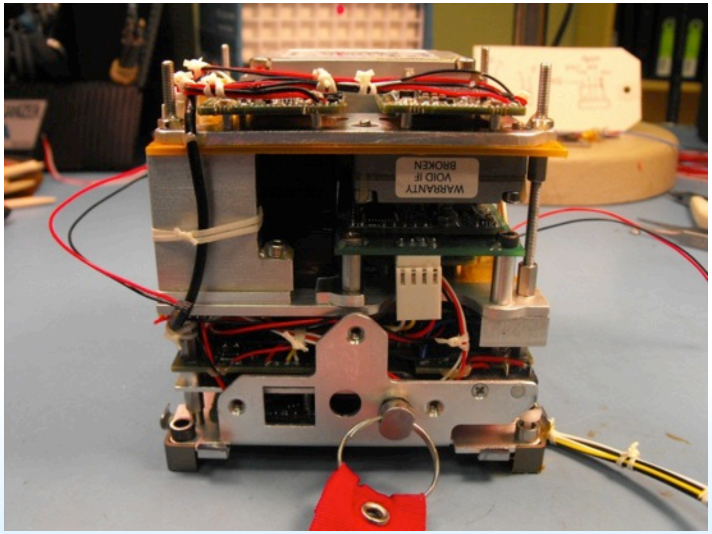
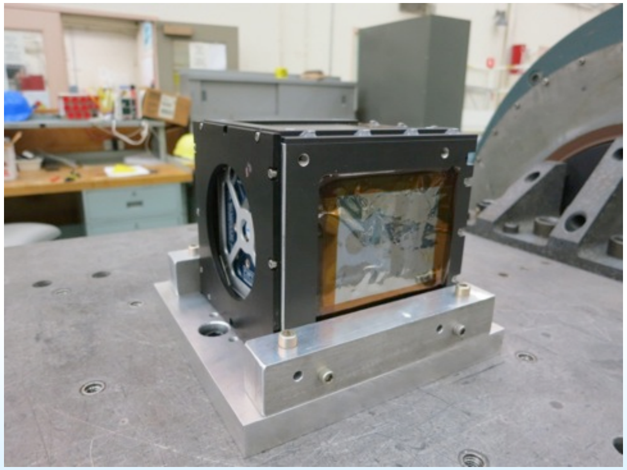
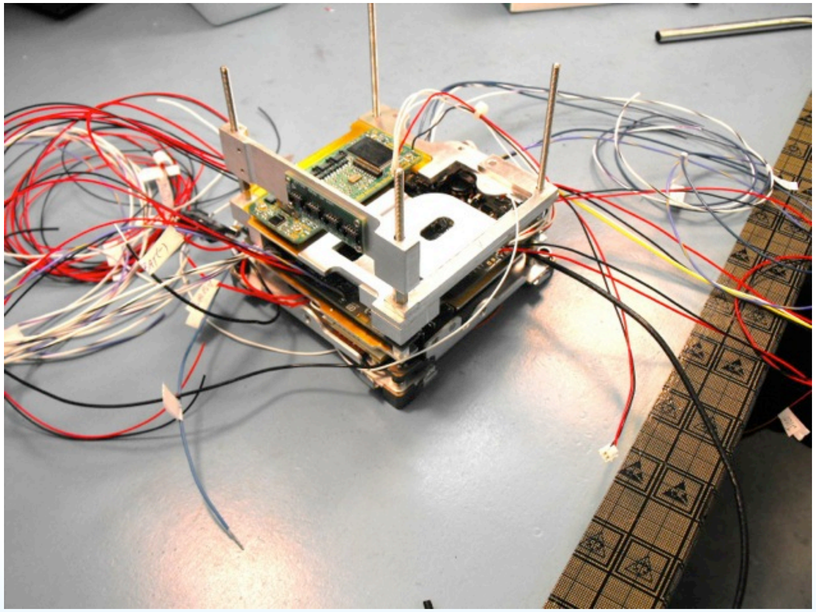




M-PACE (Improved TechEdSat)

- TechEdSat Space Plug-and-play Avionics (SPA) hardware and software – Complex and Expensive
  - Complex wiring and interconnects
  - Payload Volume – not optimized
  - Difficult to troubleshoot
- M-PACE reduces cost and complexity for CubeSats for a number of reasons
  - Use of Open Source hardware and software
  - Replaces the need for wires and wiring harnesses with snap-fit connectors
  - Able to maximize payload volume by leaving the availability for any PC104-like board with spacecraft subsystem components to connect to a backplane panel for power and avionics
  - No need for fasteners or standoffs due to the Advanced Manufacturing technologies and techniques used



Goal and Objectives

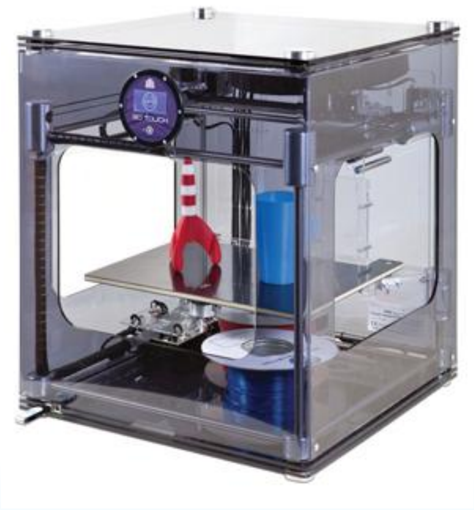
GOAL: To lower the cost, complexity, and development time of CubeSats

OBJECTIVES:

1. Use Advanced Manufacturing to develop engineering hardware for an integrated "smart" avionics panel
2. Develop modular hardware to support the next generation of CubeSat missions
3. Demonstrate the rapid development of CubeSat subsystems and components
4. Investigate slide-fit card technology for spacecraft subsystems and components so that payload volume is maximized
5. Demonstrate the ability to rapidly move from project concept to fully-tested prototype

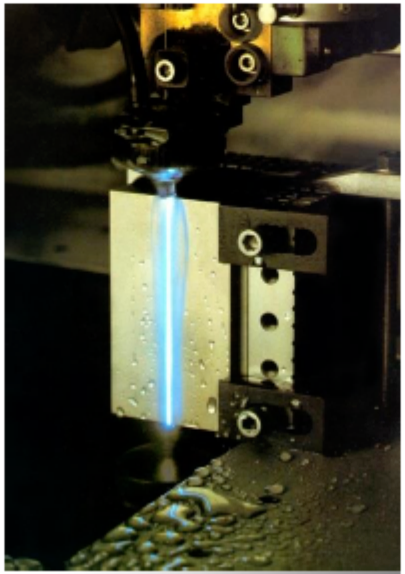
What is Advanced Manufacturing?

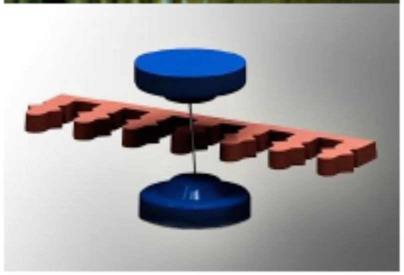
- Advanced Manufacturing
  - Use of state-of-the-art and emerging technologies and materials to create high fidelity products
  - Types of machines used in this process include 3D printers, laser cutters, desktop milling machines, etc.
  - NASA Wide (ARC, MSFC, JSC)



Advanced Manufacturing Processes

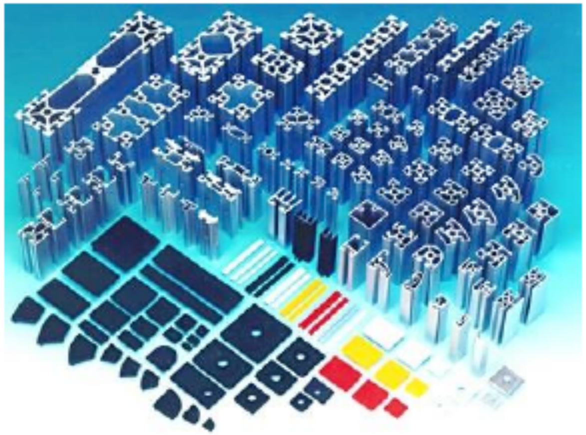
Wire EDM





Die Stamping

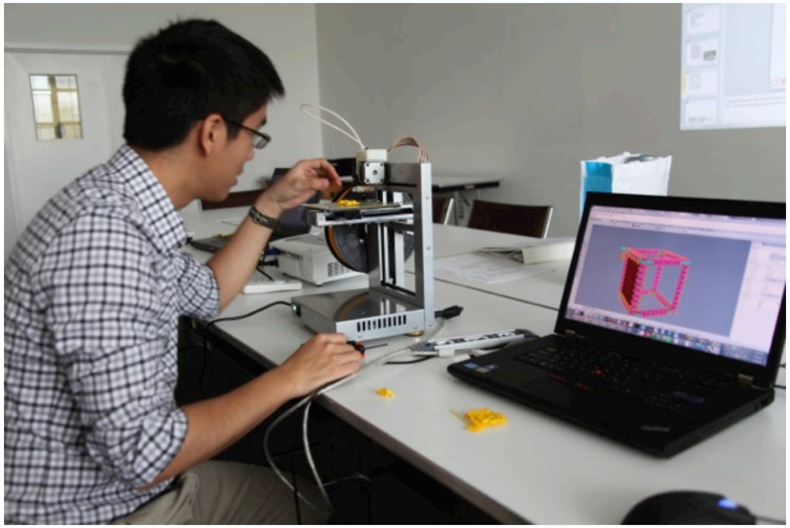
Extruded Aluminum



Waterjet

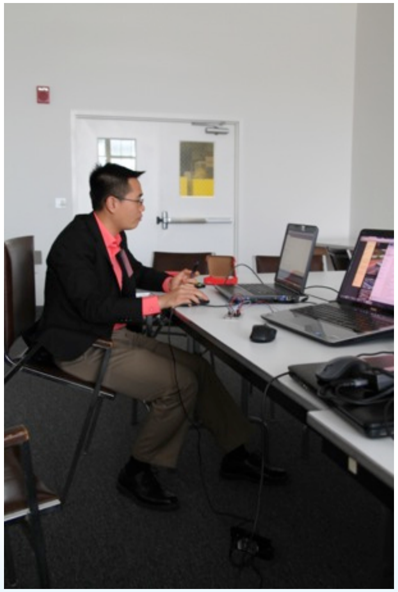
NASA Ames SpaceShop

- Funded through NASA Ames Center Chief Technologist and Engineering Directorate under the Advanced Digital Materials and Manufacturing for Space Initiative (ADMMS)
- Hands-on training and Advanced Manufacturing facility to educate and train NASA employees and interns
- Modeled after Massachusetts Institute of Technology's Fab Lab
- First of its kind within the Agency, but is considered an extension of an education framework aimed at providing people worldwide with the skills necessary to become their own inventors

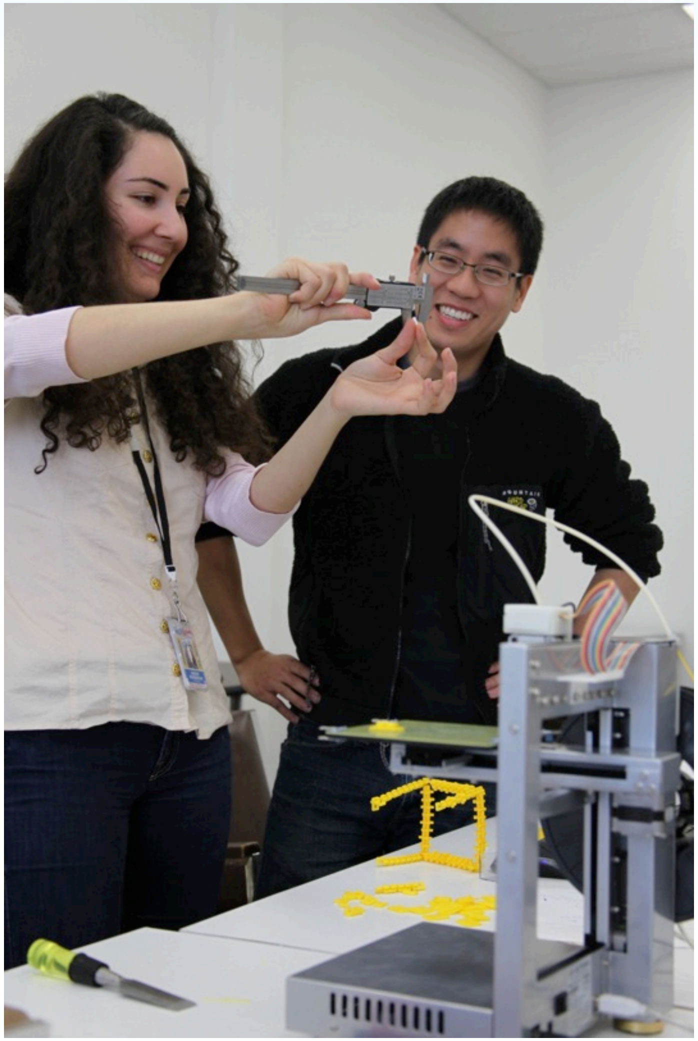


NASA Ames SpaceShop

Chao Lao working on
structure using Solidworks



Tung Dao working on
software for avionics board



Sarah Hovsepian and Greenfield Trinh using the
3D Printer to print out Digital Material pieces

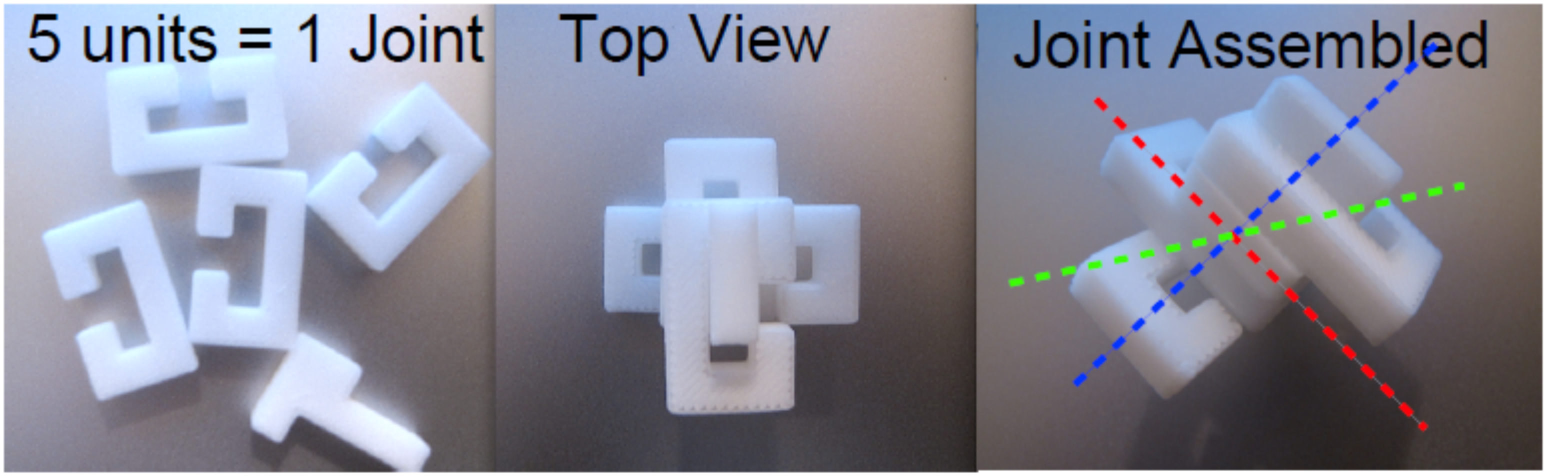
Materials that can be used in printer

- Plastic ie ABS, conductive ABS, PLA
- Metal – SLS (selective laser sintering)
  - Ti, Al, Stainless steel

M-PACE Team

- Elwood Agasid: Civil Servant Lead, NASA Ames Research Center
- Leonard Yowell: Associate Center Chief Technologist, NASA Ames Research Center
- Christopher Hartney: Project Manager, Jacobs Technology
- Sarah Hovsepian: Structures Lead, ASRC Research and Technology Solutions
- Zac Manchester: Electrical/Software Lead, Cornell University
- San Jose State University Aerospace Engineering Student Interns
  - Greenfield Trinh
  - Chao Lao
  - Brian Ha
  - Stephen Im
  - Tung Dao

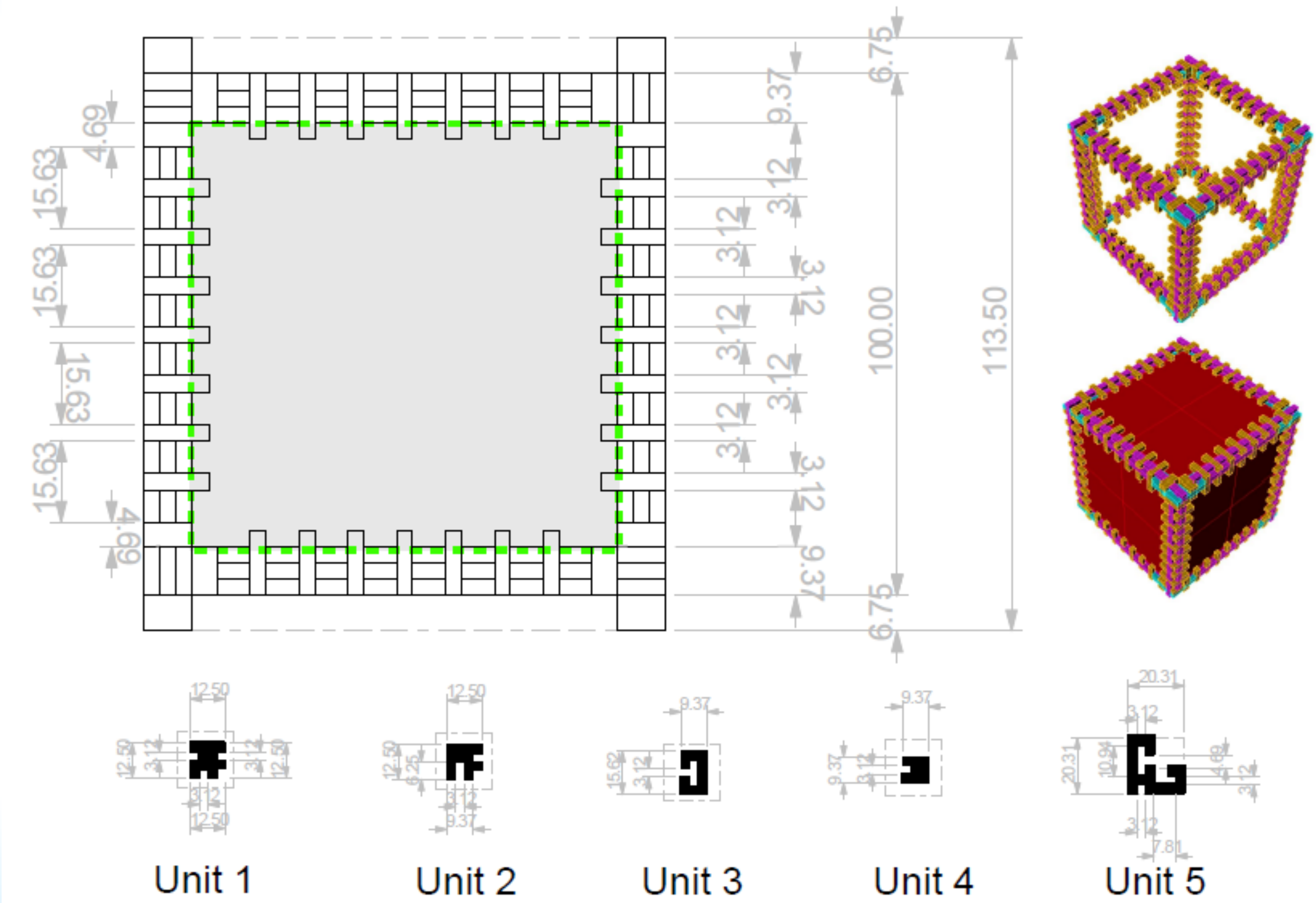
Structure – Joint Concept



Single Joint Assembly
3 Degrees of Freedom
5 Units Total
2 Types of Units

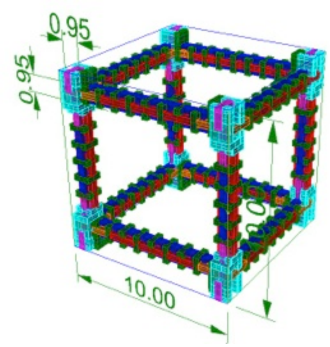
1. Rotate C Unit 90 deg
2. Rotate C Unit 180 deg
3. Rotate C Unit 270 deg
4. Rotate C Unit 360 deg
5. Insert T Unit

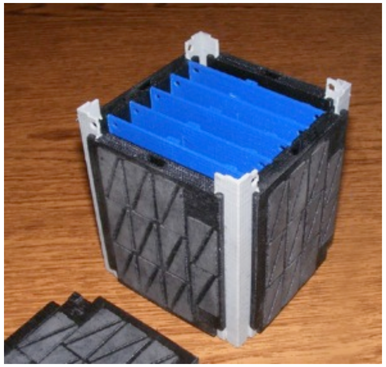
Structure Dimensions

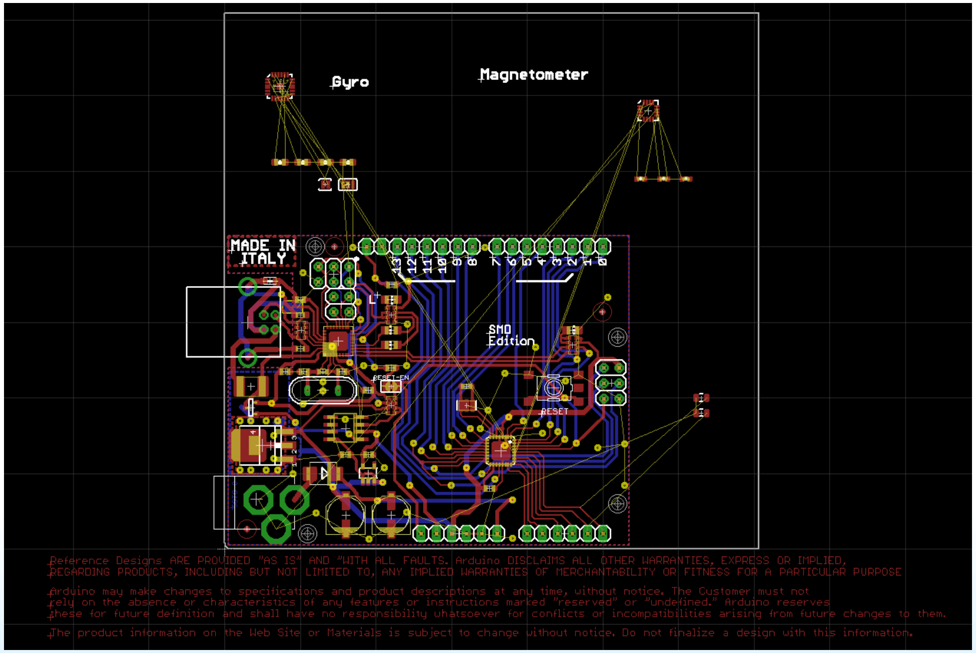


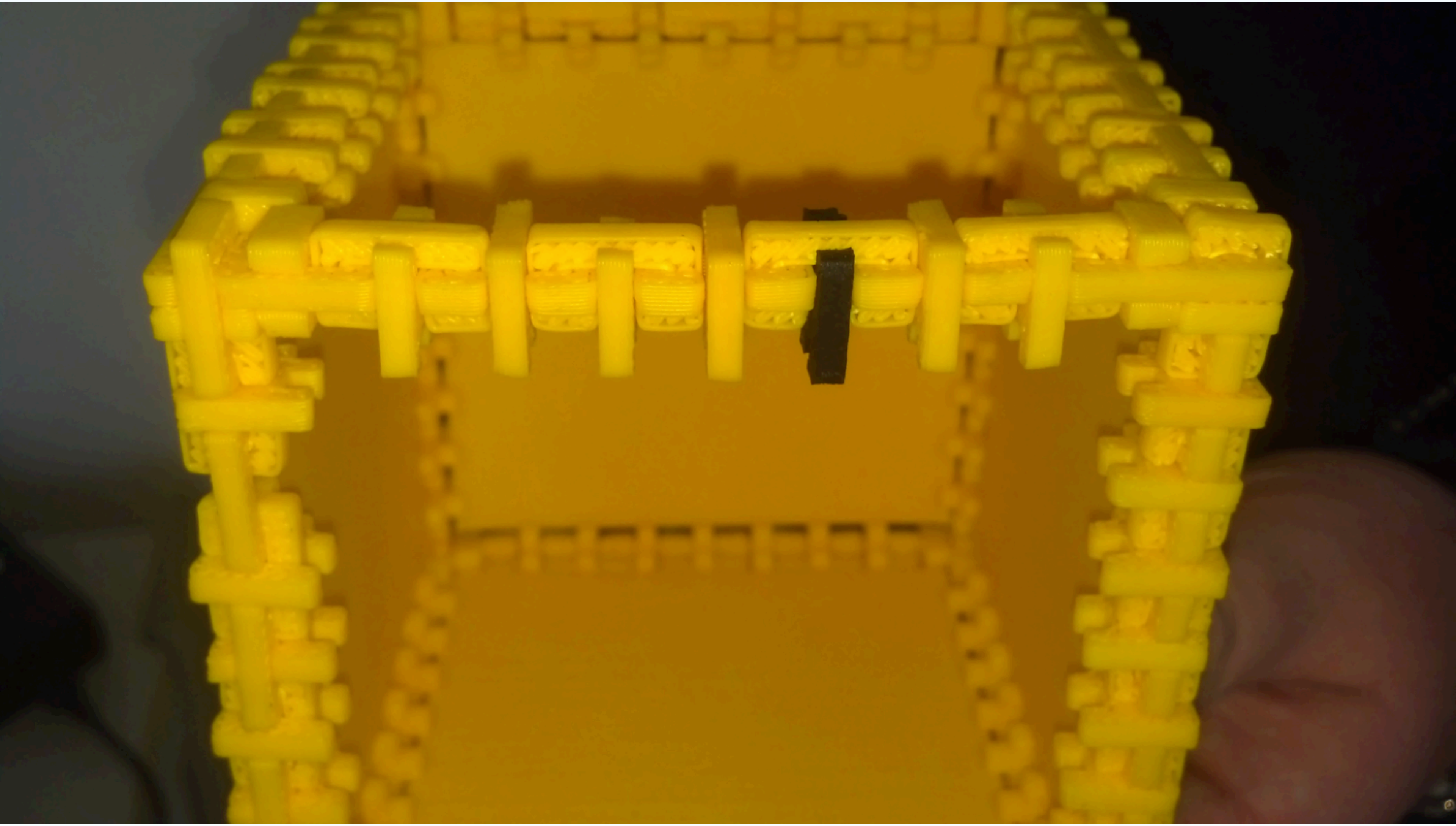
Update

- Structures
  - Ran basic FEA and tensile tests
  - Currently experimenting with SpaceShop machines (3D printers, Modela milling machine, laser cutter) to manufacture these materials
- Power
  - Li-Po Batteries w/ TASC solar panels
- Avionics
  - "Smart Panel"
    - Arduino Uno
    - Gyro
    - Magnetometer
    - Radio
    - Antenna
- Communications
  - TI CC1101 Radio
- Software
  - Arduino Open Source Programming software









Conclusion

- By demonstrating this Advanced Manufacturing capability, one can greatly reduce cost and time to design, build, prototype, and test CubeSats.
- Also, with open source hardware and software, we can design and build our own spacecraft subsystems using information already researched and developed.
- Combining both of those together, a CubeSat that takes several months to build can now take
  - several weeks…
  - or days…
  - or hours

Printed Micro-Fluidics Card