ECE499/590
Small Spacecraft Design and Engineering
(3:3:0)

Prerequisite: Undergraduate students: Junior/Senior standing
Graduate students: Minimum 9 credits already completed or POI

Instructor: Dr. Peter W. Pachowicz
OH: Wed 1-2:30pm and by an appointment
ECE Dept., Eng. Bldg., Rm.3240
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Course description:

Comprehensive study of small spacecraft design, operations, communications, computing hardware, software, sensors, power, attitude control, testing, and other topics needed for successful engineering of a spacecraft and its ground station. Review of ultra-small CubeSats already launched into the space; their hardware, software, and missions.

<u>This course will be very helpful for students interested in taking their undergraduate senior design project or graduate research project related to this topic.</u>

Course outline:

Week 1: Kickoff meeting. Introduction to space systems. Spacecraft categories and their missions. Introduction to a CubeSat concept. Evolution and new trends. SmallSats - a disruptive innovation.

Week 2: CubeSat applications. Technology development and rapid advances. Dominant role and challenges for electrical and computer engineers.
Discussion and selection of student reports/projects.

Week 3: Launch and space environments and their influence on spacecraft systems, electronics, communications, computing, operations, components, design practice, and testing.

Week 4: Satellite orbits and orientation in space. Ground area coverage. Ground communication window and strategies. Satellite tracking and scheduling. Flight operations.
Introduction to satellite communications.

Week 5: CubeSat communications. System overwiew. Ground station infrastructure. RF spectrum allocation and its implications. Doppler shift and tuning. Antenna system design. Antenna characteristics and parameters. Polarizations. Transmission lines.

Week 6: System, antenna, and receiver noise figure. Link budget components. Link budget design. Modulations. Data throuhput. Example system design.

Week 7: Link budget workshop.
Spacecraft computing infrastructure. Telemetry and commanding. Data, packet, and frame structures. Spacecraft database and files. Communications protocols. Data budget. Strategies for throughput increase and communication control.

Week 8: Spring break

Week 9: Student presentations: Review and analysis of small CubeSats already launched or selected topics in this area.

Week 10: Spacecraft power systems. Solar cells and their characteristics. Solar panels and protections. Power bus architectures. Unregulated and regulated power bus. Peak power tracking. Design tradeoffs. Ultra-small satellite power busses. Battery types, characteristics.

Week 11: Power systems for CubeSats. Power electronics. Sensors. Power system fault tolerance, fault-tolerant architectures, and electronic components. Power budget. Study of an example power system.

Week 12: Computational resources for CubeSats. Ultra-low power microcontrollers and their energy savings features. Memory systems for space applications. Resilience vs. fault tolerance. Fault tolerant embedded computing. Case study: UWE-3 multi-processor embedded system design and test results.

Week 13: Error detection and correction in embedded systems. Resilience and resilient system design. Rad-hard software. Strategies for fault tolerant and resilient software. Error detection through software techniques. Instruction flow control and data structures for resilient embedded software.

Week 14: Bringing all together in achieving a 'clean' design - A case study.
Project presentations.

Week 15: Project presentations. Review for the final.

Grading:

Design/analysis homeworks:	40%
Project (review, simulation, or development):	30%
Final (will cover 3 topics from the above list):	30%

Textbook:

No formal textbook is required. Each topic will refer to a supporting book chapter and/or paper available through GMU’s e-library or through Google search.