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

Prerequisite: UG/G status

Instructor: Dr. Peter W. Pachowicz
OH: Wed 1-2:30pm and by an appointment
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Course description:

Comprehensive study of small spacecraft design, operations, bus, 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, their hardware, software, and missions.

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. SmallSats in interplanetary missions. Examples of technological breakthroughs. Technologies needed for future missions. Challenges for engineers.
Discussion of student reports and projects.

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

Week 4: Satellite low-earth orbit and orientation in space. Ground area coverage. Ground communication window and strategies. Satellite tracking and scheduling. Flight operations.
Selection of course project.

Week 5: CubeSat bus and its modules. Two case studies.
Introduction to satellite communications. RF signal characteristics. RF spectrum allocation and its implications. Monitoring and commanding.

Week 6: CubeSat radio communication system. Ground station infrastructure. Link budget components. Data throughput. Doppler shift and tuning. Basic FM modulations.

Transmission line. Antenna characteristics. Example system design. Introduction to system, antenna, and receiver noise figure. Link budget example.

Week 7: Link budget workshop (based on practical examples.) Link budget analysis for link improvement.
Spacecraft computing infrastructure. Telemetry and commanding. On-board computer. 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 (SmallSats, CubeSat technologies)

Week 10: Spacecraft power system. 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. Li-poly battery characteristics and performance.

Week 11: Power system for a CubeSat. External interface. Power system fault tolerance. Power electronics. Power regulation and distribution. Power budget. Comprehensive 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. Fault tolerant embedded computing. Watchdog architectures. Case study: UWE-3 multi-processor embedded system design and test results.

Week 13: Radiation hardened software. Resilience vs. fault tolerancy. Error detection and correction in embedded systems. Strategies for fault tolerant and resilient software. Error detection through software techniques. Instruction flow control and data structures for resilient embedded software. Execution time methods. System testing.

Week 14: Bringing all together in achieving a 'clean' design --- Case studies: UWE-3 and SwissCube.
Project presentations.

Week 15: Project presentations.
Review for the final.

Grading:

Reports/Homeworks:	40%
Project:	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.