Introduction to Data Centers

ECE 463

Dr. Mark Dean, PhD
Fall Semester 2015

Version 1.5

REVISION HISTORY

Date	*Version*	*Author*	*Description*
14 August 2015	*0.0*	*Goodpasture*	*Initial release.*
20 August 2015	*1.0*	*Goodpasture*	*Added Pre-reading to Data Center Strategies section (08/25 and 08/27)*
28 August 2015	*1.1*	*Goodpasture*	*Changed Guest Lecturer schedule, Syllabus with schedule changes and included hyperlinks to slides that are on the class page.*

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ECE 463 Fall 2015 Class Calendar:

August 2015

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	**19** CLASSES BEGIN	**20** **Introduction to the Course** --**Mark Dean**, *Fisher Distinguished Professor, UTK* **Jim Serafin**, *Computational Facilities Complex Manager, ORNL*	21	22
23	24	**25** **DATA CENTER STRATEGIES** --**Stephen McNally**, *Operations Manager for Center for Computational Sciences, ORNL*	26	**27** **DATA CENTER STRATEGIES** -- **Stephen McNally**, *Operations Manager for Center for Computational Sciences, ORNL*	28	29
30	31					

September 2015

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
		1 **COOLING** --**David Grant**, *HPC Mechanical Engineer, ORNL*	2	**3** **COOLING** --**David Grant**, *HPC Mechanical Engineer, ORNL*	4	5
6	7 LABOR DAY	8 **INFRASTRUCTURE/ SPACE** -- **Jim Rogers**, *Director for Computing and Facilities, ORNL*	9	10 **INFRASTRUCTURE/ SPACE** -- **Jim Rogers**, *Director for Computing and Facilities, ORNL*	11	12
13	14	15 **Data Center Requirements from the Customer's Perspective** --**Mallikarjun Shankar**, *Director, Compute and Data Environment for Science (CADES)*	16	17 **PROJECT MANAGEMENT** --**Kathlyn Boudwin**, *Associate Project Director for Computing and Computational Sciences Directorate, ORNL*	18	19
20	21	22 **PROJECT MANAGEMENT** --**Kathlyn Boudwin**, *Associate Project Director for Computing and Computational Sciences Directorate, ORNL*	23	24 **ENERGY EFFICIENCY** --**David Grant**, *HPC Mechanical Engineer, ORNL*	25	26
27	28	29 **ENERGY EFFICIENCY** --**David Grant**, *HPC Mechanical Engineer, ORNL*	30			

October 2015

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
				1 Power --Rick Griffin, *Electrical Engineer, ORNL*	2	3
4	5	**6** Power --Rick Griffin, *Electrical Engineer, ORNL*	7	**8** Power --Rick Griffin, *Electrical Engineer, ORNL*	9	10
11	12	**13** Power --Rick Griffin, *Electrical Engineer, ORNL*	14	**15** FALL BREAK	**16**	17
18	19	**20** INDUSTRIAL CONTROLS --Saeed Ghezawi, *SCADA Engineer, Performance Development Corp*	21	**22** Engineer's Day No Class	23	24
25	26	**27** INDUSTRIAL CONTROLS --Saeed Ghezawi, *SCADA Engineer, Performance Development Corp*	28	**29** *Networking for a Data Center* -- Craig Thomas, *Group Leader, Network Operations, ORNL*	30	31

November 2015

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
1	2	**3** *Networking for a Data Center* -- Craig Thomas, *Group Leader, Network Operations, ORNL*	4	**5** *Commissioning a Data Center* -- Jim Rogers, *Director for Computing and Facilities, ORNL*	6	7
8	9	**10** *Management during construction of a Data Center* -- Bart Hammontree, *Technical Project Manager, ORNL*	11	**12** *Data Center Facility Operations* -- Jim Serafin, *Computational Facilities Complex Manager, ORNL*	13	14
15	16	**17** *Computing Configuration Management (DCIM)* -- Scott Milliken, *Computer Facility Manager, ORNL*	18	**19** *Computing Configuration Management (DCIM)* -- Scott Milliken, *Computer Facility Manager, ORNL*	20	21
22	23	**24** *Optional* *Datacenter tour at ORNL*	25	**26** THANKSGIVING HOLIDAY	**27**	28
29	30					

December 2015

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
		1 CLASSES END	2 STUDY DAY	**3** FINAL EXAMS	4 FINAL EXAMS	5
6	7 FINAL EXAMS	**8** FINAL EXAMS	9 FINAL EXAMS	**10** FINAL EXAMS	11	12
13	14	**15**	16	**17**	18	19
20	21	**22**	23	**24**	25	26
27	28	**29**	30	**31**		

Fall 2015 Semester

Classes Begin ..... Wednesday .....August 19
Labor Day ..... Monday ..... September 7
1st Session Ends ..... Wednesday ..... October 7
2nd Session Begins ..... Thursday ..... October 8
Fall Break ..... Thursday-Friday ..... October 15-16
Thanksgiving ..... Thursday-Friday ..... November 26-27
Classes End ..... Tuesday ..... December 1
Study Day ..... Wednesday ..... December 2
Exams ..... Thursday-Thursday ..... Dec. 3, 4, 7, 8, 9, 10
Graduate Hooding ..... Thursday ..... December 10
Commencement ..... Friday ..... December 11
Official Graduation Date ..... Friday ..... December 11

Class Description (ECE 463)

ECE 463 - Introduction to Datacenters - is required to complete the Datacenter Technology and Management minor. This is a senior-level course focused on developing multi-disciplinary insights into datacenter technology. The primary objective of this course is to deliver broad awareness of datacenter requirements, design and management technologies and methodologies. This includes: reliability, security, network systems, storage systems, industrial design, systems management, operating environments, application environments/management, operations, logistics and energy efficiencies. The program is not expected to deliver deep knowledge in a specific area, but give a student sufficient basic insight on datacenter operational characteristics and requirements. Engineering disciplines which can take this course include EE, CpE, CS, ME and IE.

Learning Outcomes

Students will be presented with a broad overview of datacenter technology and the interactions and interdependencies of datacenter components (facilities, cooling, power, management, computers, networks, OSes, applications, security, safety, etc.). Students will gain knowledge in datacenter infrastructure, operations and management best practices.

Tour of the ORNL Data Center (optional) – Nov. 24

As an optional part of this course, students will have the opportunity to visit Oak Ridge National Laboratory and tour of several data centers, including the OLCF data center, home of Titan. Students will be given a customized tour that most visitors do not receive. This tour will include a walk-through of ~50ksf of data centers and their supporting power and cooling distribution systems.

If interested, students should send an email to goodpasture@ornl.gov and cc Dr. Dean no later than September 10. For those who wish to participate will then receive an invitation from ORNL to visit. The student will need to go into the visit request and enter in their personal information. For U.S. Citizens, this information will need to be received by Nov.1. For foreign national students, information will need to be received by Sept 15.

Prerequisites by Course

COSC 130: Computer Organization

Topics that are Covered (ECE 463)

Note: This is a topical list, not a syllabus. See the syllabus for the specific semester to view the timing of the various topics.

Introduction to Course (1)

- What to expect from this course
- What is a Data Center

- Data Center Strategy (2)

- Datacenter Strategy overview
- Models (Cost and Operations)

- Cooling (2)

- Fundamentals
- Technologies
- Design
- Operations
- Future Direction

- Data Center Req., Customer's Perspective (1)

- Infrastructure/Space (2)

- Infrastructure/Space
- Security and integration
- Managing the space

- Project Management (2)

- General Topics – What is a Project and what is project management
- Project Life Cycle
- Organizational Influences
- Planning Process

- Energy Efficiency (2)

- Measures of efficiency
- Technologies (Inherent Efficiencies)
- Heat Recovery/Reuse
- Air Flow Management
- Case Studies/ White Papers

- Power (4)

- Power Systems
- Metering, SCADA, EEM systems
- Load Factors, capacity, …
- Efficiency and sustainability
- Reliability, Safety, Standards,

- Data Center Network (2)

- Industrial Controls (2)

- SCADA Overview, Brands/Types of SCADA
- System Hardware (Metering, Networking, Communications, Security Considerations)

- Commissioning a Data Center (1)

-Management During the Construction of a Data Center (1)

- Data Center Facility Operations (1)

- Computing Configuration Management – DCIM (2)

Scheduled Meeting Times						
Type	**Time**	**Days**	**Where**	**Date Range**	**Schedule Type**	**Instructors**
Class	2:10 pm – 3:25 pm	TR	Min Kao Engineering 405	19-Aug-2015 - 01-Dec-2015	Lecture	Mark Edward Dean (P)

Total number of classes – 27 (not including final exam)
Final Exam due Dec. 8

Syllabus

Check the following website for changes to syllabus:

Mtgs	Date	Topic	Materials/Assignments	Misc.
1	08/20	Introduction to Course, Expectations (grading, attendance, etc.), TA Experiences	Slides Request for Proposal – Design a Data Center Project	
2	08/25	Data Center Strategies	Slides Pre-reading: Chapters 1 and 2 *(Data Centers - Strategic Planning, Design, Construction, and Operations and Energy and Sustainability in Data Centers)* Homework: NA	**INVITED SPEAKER:** **Stephen McNally**, *Operations Manager for Center for Computational Sciences, ORNL*
3	08/27	Data Center Strategies	Slides Pre-reading: Chapter 6 *(Data Center Financial Analysis, ROI and TCO)* Homework: NA	**INVITED SPEAKER:** **Stephen McNally,** *Operations Manager for Center for Computational Sciences, ORNL*
4	09/01	Cooling	Slides Pre-reading: 2.6, 10.1-10.2.9, and 10.4-10.7 from the textbook Homework: NA	**INVITED SPEAKER:** **David Grant,** *HPC Mechanical Engineer, ORNL*
5	09/03	Cooling	Slides Pre-reading: 10.3 from the textbook Homework: NA	**INVITED SPEAKER:** **David Grant,** *HPC Mechanical Engineer, ORNL*
6	09/08	Infrastructure/Space	Slides – **under development** Pre-reading: TBD Homework: TBD	**INVITED SPEAKER:** **Jim Rogers,** *Director for Computing and Facilities, ORNL*

Mtgs	Date	Topic	Materials/Assignments	Misc.
7	09/10	Infrastructure/Space	Slides – **under development** Pre-reading: TBD Homework: TBD	**INVITED SPEAKER:** **Jim Rogers,** *Director for Computing and Facilities, ORNL*
8	09/15	Data Center Requirements from the Customer's Perspective	Slides – **under development** Pre-reading: TBD Homework: TBD	**INVITED SPEAKER:** **Mallikarjun Shankar,** *Director, Compute and Data Environment for Science (CADES), ORNL*
9	09/17	Project Management	Slides – **under development** Pre-reading: PM glossary **(under development)** Homework: 2 assignments **(under development)**	**INVITED SPEAKER:** **Kathlyn Boudwin,** *Associate Project Director for Computing and Computational Sciences Directorate, ORNL*
10	09/22	Project Management	Slides – **under development** Pre-reading: TBD Homework: TBD	**INVITED SPEAKER:** **Kathlyn Boudwin,** *Associate Project Director for Computing and Computational Sciences Directorate, ORNL*
11	09/24	Energy Efficiency	Slides – **under development** Pre-reading: 2.8, 17.3, and Chapter 23 from the textbook Homework:	**INVITED SPEAKER:** **David Grant,** *HPC Mechanical Engineer, ORNL*
12	09/29	Energy Efficiency	Slides – **under development** Pre-reading: Chapters 18 and 24 from the textbook Homework:	**INVITED SPEAKER:** **David Grant,** *HPC Mechanical Engineer, ORNL*
13	10/01	Power	Slides – **under development** Pre-reading: TBD Homework: TBD	**INVITED SPEAKER:** **Rick Griffin**, *Electrical Engineer, ORNL*
14	10/06	Power	Slides – **under development** Pre-reading: TBD Homework: TBD	**INVITED SPEAKER:** **Rick Griffin**, *Electrical Engineer, ORNL*
15	10/08	Power	Slides – **under development** Pre-reading: TBD Homework: TBD	**INVITED SPEAKER:** **Rick Griffin**, *Electrical Engineer, ORNL*
16	10/13	Power	Slides – **under development** Pre-reading: TBD Homework: TBD	**INVITED SPEAKER:** **Rick Griffin**, *Electrical Engineer, ORNL*

Mtgs	Date	Topic	Materials/Assignments	Misc.
Note – no class on 10/15 (Fall Break)				
17	10/20	Industrial Controls	Slides – **under development** Pre-reading: Chapter 14 and watch this video showing cartooned SCADA System in action Homework: TBD	**INVITED SPEAKER:** **Saeed Ghezawi**, *SCADA Engineer, Performance Development Corp*
18	10/22	**No Class – Engineer's Day**		
19	10/27	Industrial Controls	Slides – **under development** Pre-reading: TBD Homework: TBD	**INVITED SPEAKER:** **Saeed Ghezawi**, *SCADA Engineer, Performance Development Corp*
20	10/29	Networking for a Data Center	Slides – **under development** Pre-reading: Ch. 9 – Architecture Design: Data Center Rack Floor Plan and Facility Layout Design – P. 163 Ch. 14 – Data Center Telecommunications Cabling – P. 257 Ch. 20 - Virtualization, Cloud, SDN, and SDDC in Data Centers – P. 391 Homework: NA	**INVITED SPEAKER:** **Craig Thomas**, *Group Leader, Network Operations, ORNL*
21	11/03	Networking for a Data Center	Slides – **under development** Pre-reading: NA Homework: NA	**INVITED SPEAKER:** **Craig Thomas**, *Group Leader, Network Operations, ORNL*
22	11/05	Commissioning a Data Center	Slides – **under development** Pre-reading: TBD Homework:	**INVITED SPEAKER:** **Jim Rogers,** *Director for Computing and Facilities, ORNL*
23	11/10	Management During Construction of a Data Center	Slides – **under development** Pre-reading: NA Homework: NA	**INVITED SPEAKER:** **Bart Hammontree,** *Technical Project Manager, ORNL*

Mtgs	Date	Topic	Materials/Assignments	Misc.
24	11/12	Data Center Facility Operations	Slides – **under development** Pre-reading: Essential Elements of Data Center Facility Operations (White paper 196) by Robert Woolley and Patrick Donovan Homework: TBD	**INVITED SPEAKER:** **Jim Serafin,** *Computational Facilities Complex Manager, ORNL*
25	11/17	Computing Configuration Management (DCIM)	Slides – **under development** Pre-reading: Article on the race for PUE Data Center Institute Standards on Density European Commission Institute for Energy and Transport Data Centres 2015 Best Practices Guidelines Homework: TBD	**Invited speaker:** **Scott Milliken,** *Computer Facility Manager, ORNL*
26	11/19	Computing Configuration Management (DCIM)	Slides – **under development**	**Invited speaker:** **Scott Milliken,** *Computer Facility Manager, ORNL*
27	**11/24**	**ORNL's Data Center Tour (optional)**		
		Note – no class on 11/26 (Thanksgiving)		
	12/01			
	12/03	Final Projects Due		
	12/08			

Student Project:

- Design a Datacenter from a RFP (request for proposal)
- Requirements given at the beginning of the semester
- Design Proposal document
    - Maximum of 10 pages + supporting drawings
    - single spaced
    - 12pt text
- Requirements may change throughout the semester to accommodate customer needs.
- Due at the end of the semester, replaces Final Exam

Elements of Final Grade (ECE 463)

High Level Elements:

- Project documents, reports and presentations = 50% of grade

- Class assignments = 50% of grade
- Attendance (90% of classes must be attended) = 0.7 grade points out of a 4.0 grade scale.

Detail Grade Distribution:

Data Center Proposal Document	- 50%
Class Assignments	- 50%
Attendance (90% of classes must be attended)	- worth 0.7 points out of 4.0

Course Personnel:

- Faculty member in charge: Dr. Mark E. Dean
  - email: markdean@utk.edu
  - phone: 865-974-5784
  - Office hours: 3:30-5:00pm, Tuesday & Thursday
    The best way to contact me is via email or during office hours.

- IT Help: https://ithelp@eecs.utk.edu

- Guest Lecturers:
  Kathlyn Boudwin – Boudwinkj@ornl.gov
  Saeed Ghezawi – ghezawisr@ornl.gov
  David Grant – grantdr@ornl.gov
  Rick Griffin – griffinrc@ornl.gov
  Bart Hammontree - Hammontreeba@ornl.gov
  Stephen McNally – mcnally@ornl.gov
  Jim Rogers – jrogers@ornl.gov
  Mallikarjun Shankar – shankarm@ornl.gov
  Jim Serafin – serafinje@ornl.gov
  Craig Thomas – thomascd@ornl.gov