CU Boulder Graduate Level Commercial Spaceflight Operations Curriculum Overview

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Objectives

• Background/Context
• Current Status of Curriculum
• Topics Covered
• Trends Observed/Feedback Received
• Input welcome
Background & Context

Academia

Government

Industry
Background & Context

Academia

Government

Industry

COE CST
Aerospace Engineering Sciences

- 36 Faculty (28 Tenure-Track)
- 449 undergrad
- 213 grad students
  - 83% of students are U.S. Citizens

- $21.8 M in Research Awards in FY2012

- NRC ranking among top 4 PhD Aerospace Programs
  - One of the top space programs in the world

- Undergrad curriculum includes lab in each required course
- Hands-on design courses at senior and graduate level
Colorado Center for Astrodynamics Research (CCAR)

Founded 1985  Over 130 PhDs Awarded

Current Personnel:

Tenured Faculty: 12
Research Faculty:
  Research Professor: 4
  Research Associate
  (RAs, Sr. PRAs, PRAs): 15
Officer/Professional Exempt: 1
GRAs and Fellows: 72
Undergrads: 18

Total employed: 123

Remote Sensing
Space and Atmospheric Physics
Oceanography / Mass Balance / Cryosphere
Earth Gravity Field
Measurement/Modeling

Global Navigation Satellite Systems (GNSS) Applications
Spacecraft Formation Flying
Orbit and Attitude Determination
Spacecraft Navigation
Three-Body Astrodynamics
Orbital Debris Research
Background & Context

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FAA AST Overview

- FAA AST Responsibilities:

To ensure the protection of the public, property, and the national security and foreign policy interests of the United States during commercial launch and reentry activities, and to encourage, facilitate, and promote U.S. commercial space transportation.
FAA AST Context

FAA BUDGET ($15,992,596,000*)
*House Approps Committee Report

- FACILITIES & EQUIPMENT, $2,749,596,000, 17%
- RE&D, $175,000,000, 1%
- GRANTS-IN-AID FOR AIRPORTS, $3,350,000,000, 21%

FAA Operations Budget ($9,718,000,000*)
*FY12 House Approps Committee Report

- Air Traffic Organization (ATO), $7,513,850,000, 77.3%
- Aviation Safety (AVS), $1,255,000,000, 12.9%
- Finance & Management, $573,591,000, 5.9%
- Staff Offices, $298,795,000, 3.1%
- NextGen and Ops Planning, $60,064,000, 0.6%

OPERATIONS, $9,718,000,000, 61%
Background & Context

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COE CST

Industry
Background & Context

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Government

Industry

COE CST
FAA COE CST

• What? A partnership of academia, industry, and government.
• Why? To create a world-class consortium that will address current and future challenges for commercial space transportation
• How Long? 10 years
• How Much?
  – Year 1: $2M FAA Funding
  – Years 2-10: At least $1M FAA AST Funds
  – 1:1 Industry Match Required for All USG Funds
FAA COE CST
COE CST Research Areas

1. Space Traffic Management & Operations
   - 1.1 Orbital
   - 1.2 Suborbital
   - 1.3 NAS Integration
   - 1.4 Spaceport Operations
   - 1.5 Integrated Air/Space Traffic Management

2. Space Transportation Ops, Technologies & Payloads
   - 2.1 Ground System & Ops Safety Techs
   - 2.2 Vehicle Safety Analyses
   - 2.3 Vehicle Safety Systems & Techs
   - 2.4 Payload Safety
   - 2.5 Vehicle Ops Safety

3. Human Spaceflight
   - 3.1 Aerospace Phys & Medicine
   - 3.2 ECLSS & Habitability
   - 3.3 Human Factors
   - 3.4 Human Rating
   - 3.5 Personnel Training

4. Space Transportation Industry Viability
   - 4.1 Markets
   - 4.2 Policy
   - 4.3 Law
   - 4.4 Regulation
   - 4.5 Cross-Cutting Topics

On the web at bit.ly/COECSTRRR
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Curriculum Overview

• Objectives:
  – Develop one-semester course
  – Develop one-semester lab
  – Refine content based on student and industry feedback
  – Standardize and establish Graduate Certificate
  – Increase collaboration between academia and industry
Curriculum Overview

• Research
  – Student research projects investigate current constraints and explore potential solutions

• Training
  – Preparing students to enter industry with commercial perspective

• Outreach
  – Educating academia about developments in commercial space
Curriculum Objectives

Course shall serve as a bridge between theory and application to prepare real world problem solvers
Curriculum Objectives

• Comprehension of total mission sequence
  • Mission initiation to end of mission
    • Course = overview
    • Lab = implement

• Constraints on design and operations (both understand and identify)
  • Technical – what can you do
  • Policy/Legal – what are you allowed to do
  • Business – what can you afford to do
  • Practical – how do you adapt
Curriculum Objectives

• Understanding of and insight into current industry practices
  • Comprehension of current industry practices
    • Past to present
    • Keep vs Change?
  • Critical review of potential improvements

• Overview of project management and team dynamics

• Cross cutting theme (through all objectives): RISK
  • Quantify and understand risk vs cost
Course Status

• Lecture course offered Fall 2011 & 2012
  – Total students enrolled: 48
    • On campus: 33
    • Off campus: 15

• Lab course offered Spring 2013
  – Total students enrolled/involved: 7
Operations Lab
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Topics Covered - Lecture

• Industry background/context
• Technical fundamentals
  – Mission requirements/Orbital Mechanics
  – Launch propulsion/vehicles & launch operations
  – Orbital transfers and operations
  – Payload management
  – End-of-mission
  – Ground Segment
  – Human Spaceflight
• Telecommunications fundamentals
  – Technical specifics and applications
• Industry insight on operations
Topics Covered - Lab

• Operations process and considerations
• Baseline mission is GEO communication satellite
  – Pre-launch and launch operations
  – Satellite transfer orbit
  – Attitude determination/control
  – Orbit determination/maintenance
  – End-of-life considerations
• Open-ended ConOps for selected mission
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“I really enjoy this course. It is information that every aerospace engineer should know”

“It is extremely valuable to gain insight from professionals, as opposed to the usually somewhat-limited academic presentation of material”

“The guest lectures, overall, have been very enlightening. It is very often that I come away from a guest lecture inspired, excited, and feeling more informed than when I entered.”

“This course has really stood out to me so far in how everything is very investigative.”
Student Feedback - Challenges

• Students commented that open-ended assignments were overly challenging.
  – Continued effort to balance work-load of assignments with open-ended expectations
  – Feature of the course is that we don’t spell out everything required

• Lab assignments using STK have been criticized as both too easy and too difficult.
  – Modification of labs to be more diverse beyond astrodynamics
Student Projects

• Management and Integration of Commercial Spaceflight Operations into the National Airspace System
• Space Situational Awareness and Space Traffic Management
• Export Control Limitations
• Space Tourism
• Space Resource Utilization
• Orbital Fuel Depots
• Suborbital Point-to-Point Transportation
• Magnetic Launch and Reusable Launch Vehicles
• Evolution of the Orbital Launch Vehicle Industry
• Electric Ion Propulsion: Legacy and Applications
Student Projects

STM Functions

- Issues licenses
- Has Range Responsibilities
- Supports Launch Decisions
- Can track orbital objects
- Regulates Reentry/End-of-Life

Agency

- Fed Aviation Admin
- Dept of Defense
- NOAA
- NASA
- FCC

“Houston, we have a problem.”

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<th>Authority</th>
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<th>Active Debris Removal</th>
<th>Code of Conduct</th>
<th>National Security</th>
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Future Efforts

• Incorporate Interdisciplinary Telecommunications Program (ITP)
• Enable distance learning in lab
  – Focus on virtual collaboration tools
• Expand industry involvement via distance learning
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We Welcome Your Feedback

• What do you think is important to focus on?

• What are the emerging trends within industry?

• Where can we add value?
  – Instruction
  – Research
  – Other?