COMMERCIAL SPACEFLIGHT OPERATIONS: GRADUATE LEVEL CURRICULUM DEVELOPMENT

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Although the FAA has sponsored this project, it neither endorses nor rejects the findings of this research. The presentation of this information is in the interest of invoking technical community comment on the results and conclusions of the research.
Outline

• Background/Context
• Overview of Task
• Development of Course Curriculum
• Course Execution
• Feedback
• Looking Forward
• Conclusions
Background: CU AES

• CU Boulder
  – 30,000 students (25k undergrad, 5k graduate)
  – $250 million in research activities

• AES
  – Over 400 Undergraduates, over 200 graduate
  – $21.8 million in funded research (2011)
Background: FAA COE
Background: FAA COE

• 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
Background: FAA COE

1. Space Traffic Management & Operations
   - 1.1 Orbital STM
   - 1.2 NAS Integration & Spaceport Operations

2. Space Transportation Operations, Technologies & Payloads
   - 2.1 Ground System & Operations Safety Tech’s
   - 2.2 Vehicle Safety Analyses
   - 2.3 Vehicle Safety Systems/Tech’s
   - 2.4 Payload Safety
   - 2.5 Vehicle Safety Operations

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

4. Space Transportation Industry Promotion
   - 4.1 Markets
   - 4.2 Policy
   - 4.3 Law
   - 4.4 Regulation
Overview of Task

- 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
Overview of Task

• 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
Development of Curriculum

• Draft academic objectives based on industry discussion
• Solicit feedback on academic objectives
  – AIAA Spaceflight Operations Meeting
  – Over 24 industry/partner organizations
• Define curriculum topics and solicit feedback
• Identify subject matter experts to develop and deliver content
Course shall serve as a bridge between theory and application to prepare real world problem solvers
Development of Curriculum

• 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
Development of Curriculum

- 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 Execution

• Total students enrolled (2011): 28
  – 19 on-campus
  – 9 off-campus (enabled by distance technology)
• Total students enrolled (2012): 20
  – 14 on-campus
  – 6 off-campus
## Course Execution

<table>
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<th>Theme</th>
<th>Topic/Subject</th>
<th>Speaker</th>
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<td><strong>Background</strong></td>
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<tr>
<td>Lecture 1</td>
<td>Course introduction</td>
<td>Cheetham/Born - CU</td>
<td>8.23.2011</td>
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<tr>
<td>Lecture 2</td>
<td>Industry &amp; Government intro</td>
<td>Steve Lindsey - SNC</td>
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<td>Lecture 3</td>
<td>Industry &amp; Government Challenges</td>
<td>Mike Gold – Bigelow Aerospace</td>
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<td><strong>Launch</strong></td>
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<td>Launch Vehicle Overview</td>
<td>Emil Heeren - CU</td>
<td>9.6.2011</td>
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<td>Lecture 4</td>
<td>Human launch considerations</td>
<td>John Reed - ULA</td>
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<td>Lecture 5</td>
<td>Suborbital flight</td>
<td>Jon Turnipseed – Virgin Galactic</td>
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# Course Execution

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<td>Bill Possel - LASP</td>
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<td>Spacecraft Subsystems</td>
<td>Michael Begley - LMCO</td>
<td>9.29.2011</td>
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<td>Lecture 5</td>
<td>Spacecraft Subsystems II</td>
<td>Scott Mitchell – Ball Aerospace</td>
<td>10.4.2011</td>
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<td>Lecture 6</td>
<td>Industry Overview</td>
<td>Alan Stern - SwRI</td>
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<td>Lecture 7</td>
<td>Payloads</td>
<td>Martin Taylor/Michael Mahoney - GeoEye</td>
<td>10.11.2011</td>
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<td>Human Factors</td>
<td>Jim Voss - SNC</td>
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<td>Lecture 9</td>
<td>On-Orbit - OD</td>
<td>Jeff Parker - JPL</td>
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<td>Lecture 10</td>
<td>Conjunction/Debris</td>
<td>Dave Vallado - AGI</td>
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<td>Lecture 11</td>
<td>Ground station operations/design</td>
<td>Byron Miller – Clear Channel Satellite</td>
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<td>Re-entry Overview/Review</td>
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<td>End-of-mission options</td>
<td>Larry Williams/Scott Henderson - SpaceX</td>
<td>11.1.2011</td>
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<td>Quality Sciences/Cost-Plus vs. Commercial Contracting</td>
<td>Jeff Luftig - CU</td>
<td>11.3.2011</td>
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## Course Execution

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<td>Lecture 1</td>
<td>Mission design</td>
<td>Mike McGrath - LASP</td>
<td>11.8.2011</td>
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<td>Construction/Integration Overview</td>
<td>David Termohlen – Orbital Sciences Corp.</td>
<td>11.10.2011</td>
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<td>Financial/Contracting Overview</td>
<td>Clay Mowry - Arianespace</td>
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<td>On-orbit Fuel Depots/Satellite Servicing</td>
<td>Jon Goff – Altius Space Machines</td>
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<td>Overview/Summary/Current issues</td>
<td>Mark Sirangelo - SNC</td>
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<td>Space Policy Overview</td>
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<td>Course Summary</td>
<td>Cheetham - CU</td>
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<td>Student Presentations</td>
<td>Individual research projects</td>
<td>Selected by students and assisted by industry</td>
<td>FINALS</td>
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Course Execution

Assignments

– Weekly discussion
– 4 Open Ended Assignments
– 4 Labs
– 1 Research Paper
Industry Partners

Colorado Center for Astrodynamics Research
The University of Colorado
Feedback

Course Content Overall

- Very - 42%
- Somewhat - 54%
- Neutral - 4%

Lectures

- Very - 50%
- Somewhat - 42%
- Neutral/Below - 8%

Comparison

- Exceeds - 46%
- Same - 42%
- Below - 12%

“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”

“I am finishing my Master’s degree this semester and a lot of this information is useful to me in understanding how the industry works”

“I like the variety of topics that are covered”

“This course has really stood out to me so far in how everything is very investigative.”
Looking Forward

• Course Fall 2012
Looking Forward

• Lab Spring 2013
Operations Lab Concept
Conclusions

• Operations lecture course has attracted student and industry interest
• Operations lab has shown extensive preliminary interest
• Applied operations curriculum has initially proven fruitful
• Industry is interested in having better informed students graduating
• Future expansion is expected
Questions