Educating Future Systems Engineers: US Military Academy Reception-Day
Simulation and Optimization

LTC Simon R. Goerger, PhD
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Agenda

- Department of Systems Engineering (DSE) Process Model
- Systems Engineering Management Process
- Research & Educational Environment
- Capstones
- Reception-Day Capstone
- Study Conclusions
- Summary
Researching the Army’s Future
Developing Tomorrow’s Leaders
## DSE Majors: Class of 2008

<table>
<thead>
<tr>
<th>Major</th>
<th>Core Courses</th>
<th>Major Courses</th>
<th>Total Courses</th>
<th>Cadets (% of Class)</th>
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<tbody>
<tr>
<td>**Systems Engineering *</td>
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<td>18</td>
<td>44</td>
<td>19 (1.8)</td>
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<tr>
<td>**Operations Research</td>
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<td>15</td>
<td>42</td>
<td>9 (0.8)</td>
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<td>**Engineering Management *</td>
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<td>18</td>
<td>44</td>
<td>64 (5.9)</td>
</tr>
<tr>
<td>**Information Systems</td>
<td>27</td>
<td>17</td>
<td>44</td>
<td>6 (0.6)</td>
</tr>
<tr>
<td>Engineering</td>
<td><strong>Systems Management</strong></td>
<td>27</td>
<td>13</td>
<td>40</td>
</tr>
<tr>
<td><strong>Total/Ave</strong></td>
<td><strong>26.2</strong></td>
<td><strong>16.2</strong></td>
<td><strong>42.8</strong></td>
<td><strong>110 (10.2)</strong></td>
</tr>
</tbody>
</table>

* ABET Accredited

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Researchers the Army’s Future
Developing Tomorrow’s Leaders
Systems Engineering and Management Process

- **Environment**
  - Cultural
  - Technological
  - Economic
  - Historical

- **Problem Definition**
  - Needs Analysis
  - Value System Design

- **Design & Analysis**
  - Alternatives Generation
  - Modeling & Analysis

- **Decision Making**
  - Alternative Scoring
  - Decision

- **Implementation**
  - Planning for Action
  - Execution
  - Assessment & Control

- **Assessment & Control**

--- Assessment & Feedback -------
Advanced Individual Academic Development (AIAD)

- Two types of experiences
  - Broaden academic experience
  - Conduct capstone background research
- Support academic program objectives
- Summer 2005:
  - 84 cadets
  - 5 countries (17 states including D.C.)
  - 45 sponsors
Research & Educational Environment
Capstones

- All capstones are lead by Ph.D.s
- Where possible, AIAD opportunities precede capstones
- Generally 3-5 cadets per capstone team
- Work significant problem with real client for two semesters
USMA R-Day Design Simulation

Issue:
- In the past, some R-Day operations have not functioning at optimal rates
  - Inefficiencies in R-Day operations cause back-ups that leave some new cadets lacking proper training and/or attire for the Oath Ceremony
- Previous analyses of R-Day operations focused on thirteen Thayer Hall stations, the USCC stations (non-linear processes) were not included
  - Incomplete analysis has lead to local instead of global optimizations

Approach:
- Use SEMP to review past R-Day activities, datasets, maps, and projects to identify critical points and areas of potential improvement
- Develop a simulation to determine optimal parameters for:
  - Station order
  - Staff levels for squad leaders & barbers
  - Optimal bus & squad leader arrival rates

Objective:
- Build on previous R-Day studies to provide a global optimization
- Create a model/simulation to be used as a possible test bed for future adjustments to R-Day activities

Outcomes:
- Modeled USCC areas (non-linear process) incorporating the model with an improved Thayer Hall model (linear process) to yield a more complete simulation for analysis of the system
- Identified optimal staff numbers, execution order for USCC stations, and processing guidelines to complete in-processing as efficiently/quickly as possible
AY 06 Capstone Research

- American Insurance Group (AIG) Assessment of Catastrophic Models
- Black Dart
- Border Security
- BRAC
- Casualty Assistance Officer Wizard
- Developing New Readiness Metric
- First Term Dental Readiness (FDTR): Fort Benning, GA
- First Term Dental Readiness (FDTR): Fort Jackson, SC
- Flying the Warrior UAV within the National Airspace System
- Future Force Warrior Simulation
AY 06 Capstone Research

- Future Forecasting
- GIS Integration Into Virtual West Point
- Hypersonic High-Intensity Anti-Ballistic Missile Systems
- In/Out Processing
- Integrated Base Defense
- Logistical Support for a Lunar Base
- Leaders Tactical Medical Monitoring Collective (LTM2C)
- MAGIC *
- Mini-Baja *
- OneSAF Behavioral Specifications

* With Dept C/ME
AY 06 Capstone Research

- Product Manager-Individual Combat Equipment (PM-ICE) Study
- Reception-Day (Plus Day 1 and Day 2) Simulation Study
- Scramjet Topic
- Sustainability of the Brigade Combat Team
- Homeland Security Resilience Metric(s)
- Unmanned/Robotic Vehicles
Problem Statement

Stream line Reception-Day activities for in-processing new cadets into the Corps of Cadets from the initial arrival of candidates at Thayer Hall until the start of the Oath Ceremony to ensure all critical tasks and training are completed prior to the Oath Ceremony at 1745.
Assumptions

Assumptions due to:
- Modeling constraints
- The need to account for imperfect data

Examples:
- Candidates return to Company Holding Area after each station
- Candidates stay together as a single squad throughout the USCC portion of R-Day
- All Candidates have trousers in hand when they leave Issue Point #2 (IP2)
- Drill 1 and Drill 2 are combined
- Every Candidate goes to the Barber Shop
- IP3 and Company In-Processing grouped together
Process Flow: Thayer Hall

START

Baggage Check

Admissions

Smart Card

DENTAC

Treasurer

Issue Point 1

Changing Area

Tattoo Check

Medical Check

Oath

Immunization

Company Assignment

Company Holding Area

USCC

Researching the Army’s Future
Developing Tomorrow’s Leaders
ProModel: Thayer Hall

Model Built By:
CDT Stephen P. Fuller
CDT Jeffrey D. Glick
CDT Thomas P. Kavanaugh
CDT Arlan C. Sheets

Faculty Advisor:
LTC Simon R. Goerger, PhD
Process Flow: USCC

Thayer Hall

- Company Reception
- Lunch
- Issue Point 2
- Drill 1
- Issue Point 3
- Drill 2
- Trouser Issue
- Company In-Processing
- Barber
- Formation at 1745

END

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Functional Flow: USCC

- Leave Thayer
  - Candidates <30 in Barber Shop?
    - Yes → Barber Shop
    - No → Holding Area

- Holding Area
  - 1000hrs
    - Time <1400hrs
      - Yes → Mess Hall
      - No → Trouser Issue
  - No
    - Candidates <50 and not been to Trouser?
      - Yes → Red Sash
      - No → Drill

- Trouser Issue
  - Candidates <10 and not been to Red Sash?
    - Yes → Red Sash
    - No → Inprocessing

- Red Sash
  - Drill
  - Inprocessing
  - Barber Shop
    - Wait till Barbershop <30
      - Yes → Barber Shop
      - No → Wait till 1000
        - Yes → Not Eaten and T=1000hrs?
          - Yes → Barber Shop
          - No → Trouser Issue <50
            - Yes → Barber Shop
            - No → Trouser Issue <10
              - Yes → Barber Shop
              - No → Red Sash <10
                - Yes → Barber Shop
                - No → Red Sash

- Wait till 1000
  - Yes → Not Eaten and T=1000hrs?
    - Yes → Barber Shop
    - No → Trouser Issue <50
      - Yes → Barber Shop
      - No → Trouser Issue <10
        - Yes → Barber Shop
        - No → Red Sash <10
          - Yes → Barber Shop
          - No → Red Sash

- USCC Complete
ProModel: USCC
Alternatives/Issues

- Arrival rates of busses to Thayer Hall
- *Pick-up rates of the candidates from Thayer Hall*
- Routing of candidates in order to reduce average wait times at the barbershop and delaying trouser issue
- Number of Squad Leaders available
- Number of barbers available
Alternatives

- Arrival rates of busses to Thayer Hall

  *Bottom Line: Buses should arrive to Thayer Hall approximately every 8:30*

<table>
<thead>
<tr>
<th>Inter-Arrival Time</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

Arrival Times to Thayer Hall
Alternatives

- Pick-up rates of the candidates from Thayer Hall
- *Bottom Line: Longer inter-arrival time = larger squads = shorter R-day*

![Graph](image-url)
Routing of candidates in order to reduce average wait times at the barbershop and delaying trouser issue

**Bottom Line:** Limit the flow of cadets into the barbershop when trouser issue still incomplete

<table>
<thead>
<tr>
<th>Rule</th>
<th>Time to Complete R-Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haircut First</td>
<td>9:02</td>
</tr>
<tr>
<td>Trousers First</td>
<td>8:58</td>
</tr>
</tbody>
</table>
Alternatives

- Number of Squad Leaders available
- **Bottom Line:** Recommend 14 squad leaders; too many squad leaders creates too many (and smaller) squads moving in system

![Graph showing the relationship between the number of squad leaders available and the total time to complete R-Day. The graph indicates that 14 squad leaders is the optimal number, as it results in the lowest total time.]
Alternatives

- Vary the number of barbers available
- *Bottom Line: 16 Barbers cost effective*
**Increase the Size of the Corps**

- **Bottom Line:** Time to complete R-day shows linear growth with increasing size of Corps

<table>
<thead>
<tr>
<th>Bus Trips</th>
<th>Cadets</th>
<th>Time to Complete R-Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>1144</td>
<td>8.25</td>
</tr>
<tr>
<td>27</td>
<td>1188</td>
<td>8.68</td>
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<tr>
<td>28</td>
<td>1232</td>
<td>8.78</td>
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<td>29</td>
<td>1276</td>
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<td>30</td>
<td>1320</td>
<td>9.05</td>
</tr>
<tr>
<td>31</td>
<td>1364</td>
<td>9.45</td>
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<tr>
<td>32</td>
<td>1408</td>
<td>9.85</td>
</tr>
<tr>
<td>33</td>
<td>1452</td>
<td>9.83</td>
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<tr>
<td>34</td>
<td>1496</td>
<td>10.42</td>
</tr>
<tr>
<td>35</td>
<td>1540</td>
<td>10.65</td>
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<tr>
<td>36</td>
<td>1584</td>
<td>10.9</td>
</tr>
<tr>
<td>37</td>
<td>1628</td>
<td>11.95</td>
</tr>
</tbody>
</table>

**Graph:**
- **Y-axis:** Time (Hours)
- **X-axis:** Number of Cadets
- **Points:** (1144, 8.25), (1232, 8.78), (1320, 9.05), (1408, 9.85), (1452, 9.83), (1496, 10.42), (1540, 10.65), (1584, 10.9)
Effect of Decreased Control Flow Measures

When you decrease control flow measures, the amount of time needed to complete R-Day increases.

- **SCENARIO**: Allow Squad Leaders to randomly decide where to take his/her squad until complete:

  **RESULT**: 25:16 hours (*Actual time = 7:46 AM, R-Day + 1*)

- **SCENARIO**: Ignore the counters at the various stations:

  **RESULT**: Approximately 16:30 hours (*Actual time = 10:30 PM*)
Picked four critical parameters

Understand the interaction of:

- Bus Arrival Rates
- Squad Leader Pick-Up Arrival Rates
- Squad Leaders Available
- Barbers Available
$x_i = \text{average time at stations 1, 2,...i (} a_i \text{ is the associated weight for each station)}$

$x_j = \text{number of minutes to complete R-Day (} b_j \text{ is the associated weight for each station)}$

$x_k = \text{cost per bus driver, barber, and squad leader (} c_k \text{ is the associated weight for each station)}$

$x_l = \% \text{ complete at stations 1, 2,...l (} d_l \text{ is the associated weight for each station)}$

$x_m = \text{total throughput of the simulation (} e_m \text{ is the associated weight for each station)}$
Objective Function:

\[ \text{Min } z_1 = \sum a_i x_i + \sum b_j x_j + \sum c_k x_k \]

\[ \text{Max } z_2 = \sum d_l x_l + \sum e_m x_m \]

\[ z_0 = z_2 - z_1 \]
### SimRunner Optimization Results

<table>
<thead>
<tr>
<th>Bus Arrival Rates (Min)</th>
<th>Squad Leader Pick-Up Arrival Rates (Min)</th>
<th>Number of Squad Leaders Available (per Company)</th>
<th>Number of Available Barbers</th>
<th>Objective Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>14</td>
<td>13</td>
<td>12</td>
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<tr>
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<tr>
<td>6</td>
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<td>15</td>
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<tr>
<td>8</td>
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Researching the Army’s Future  
Developing Tomorrow’s Leaders
## SimRunner Optimization Results

<table>
<thead>
<tr>
<th>Method</th>
<th>Bus Arrival Rates (Min)</th>
<th>Squad Leader Pick-Up Arrival Rates (Min)</th>
<th>Number of Squad Leaders Available (per Company)</th>
<th>Number of Available Barbers</th>
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</thead>
<tbody>
<tr>
<td>Four Factor Optimization</td>
<td>7</td>
<td>14</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>One Factor Optimization</td>
<td>8</td>
<td>14</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Actual for 2004</td>
<td>~9</td>
<td>~10</td>
<td>Average 13</td>
<td>Average 14</td>
</tr>
<tr>
<td>Actual for 2005</td>
<td>~8</td>
<td>~15</td>
<td>Average 13</td>
<td>Average 14</td>
</tr>
</tbody>
</table>
Study Conclusions

- Limited resources requiring non-linear utilization can be optimized by establishing flexible process thresholds which allow freedom of execution.

- Process thresholds need to be subjectively altered by a central command (operations center) throughout the day to maximize throughput.

- Real-time information of status of key areas is required to allow system administrators (squad leaders) and central command (operations center) to execute tasks in a timely manner.

- Impact to USMA and the Army:
  - Efficiency (*2005 process shaved nearly 30 minutes from 2004 time*)
  - Cost-savings
Summary

The USMA systems engineering undergraduate program combines a sound mathematical foundation with a comprehensive methodology, viable techniques, and appropriate computer technology. It culminates with an open-ended, real world capstone project to solidify the academic experience. The 2005 Reception-Day Project is an example of the level of effort and type of product produced by a student completing the DSE Program.
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