8th Annual
Systems Engineering
Conference

Thursday, 27 October 2005

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

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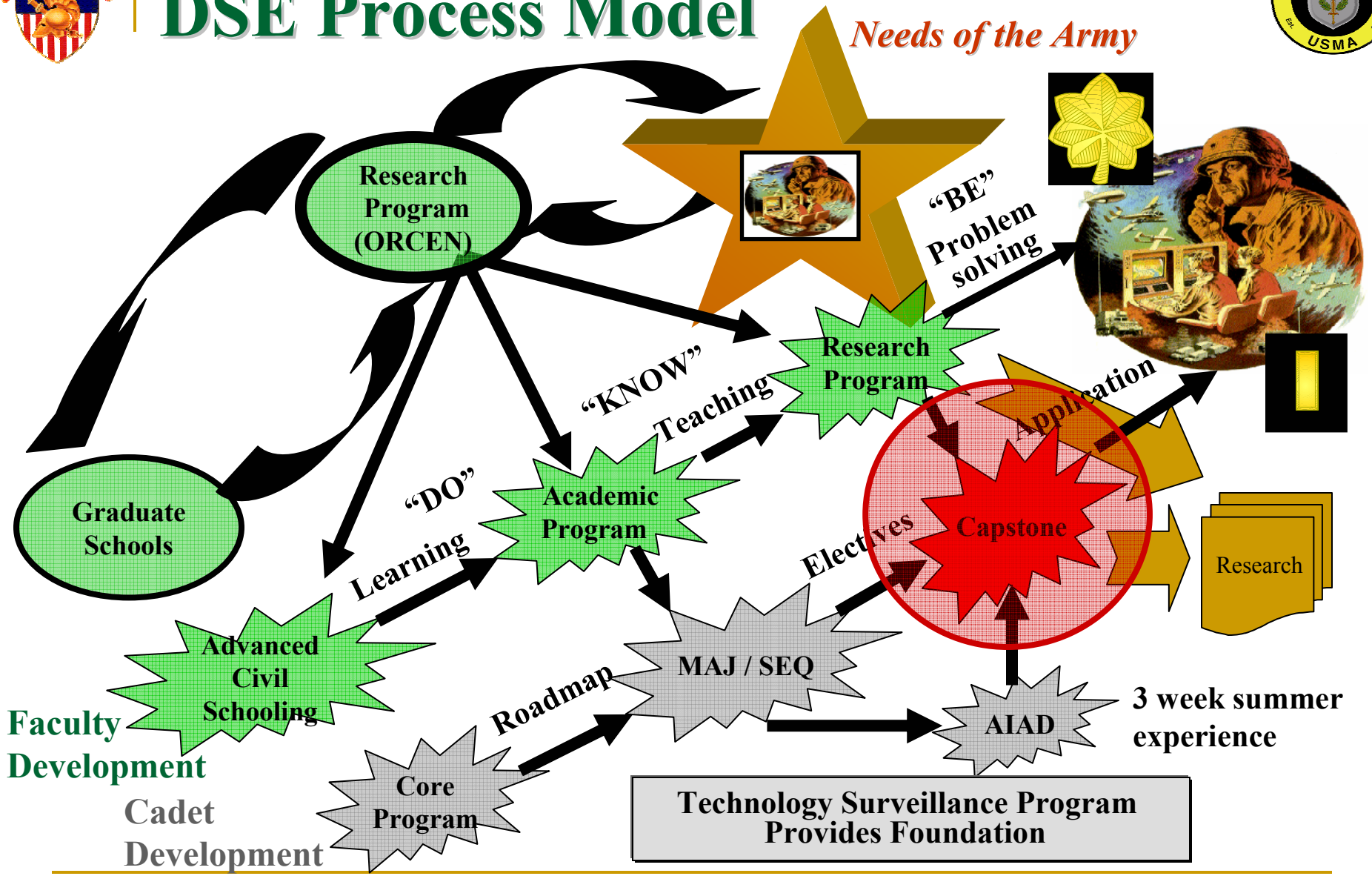
Operations Research Center of Excellence
Researching the Army's Future
Developing Tomorrow's Leaders

Agenda

- Department of Systems Engineering (DSE) Process Model
- Systems Engineering Management Process
- Research & Educational Environment
- Capstones
- Reception-Day Capstone
- Study Conclusions
- Summary

DSE Process Model



Researching the Army's Future
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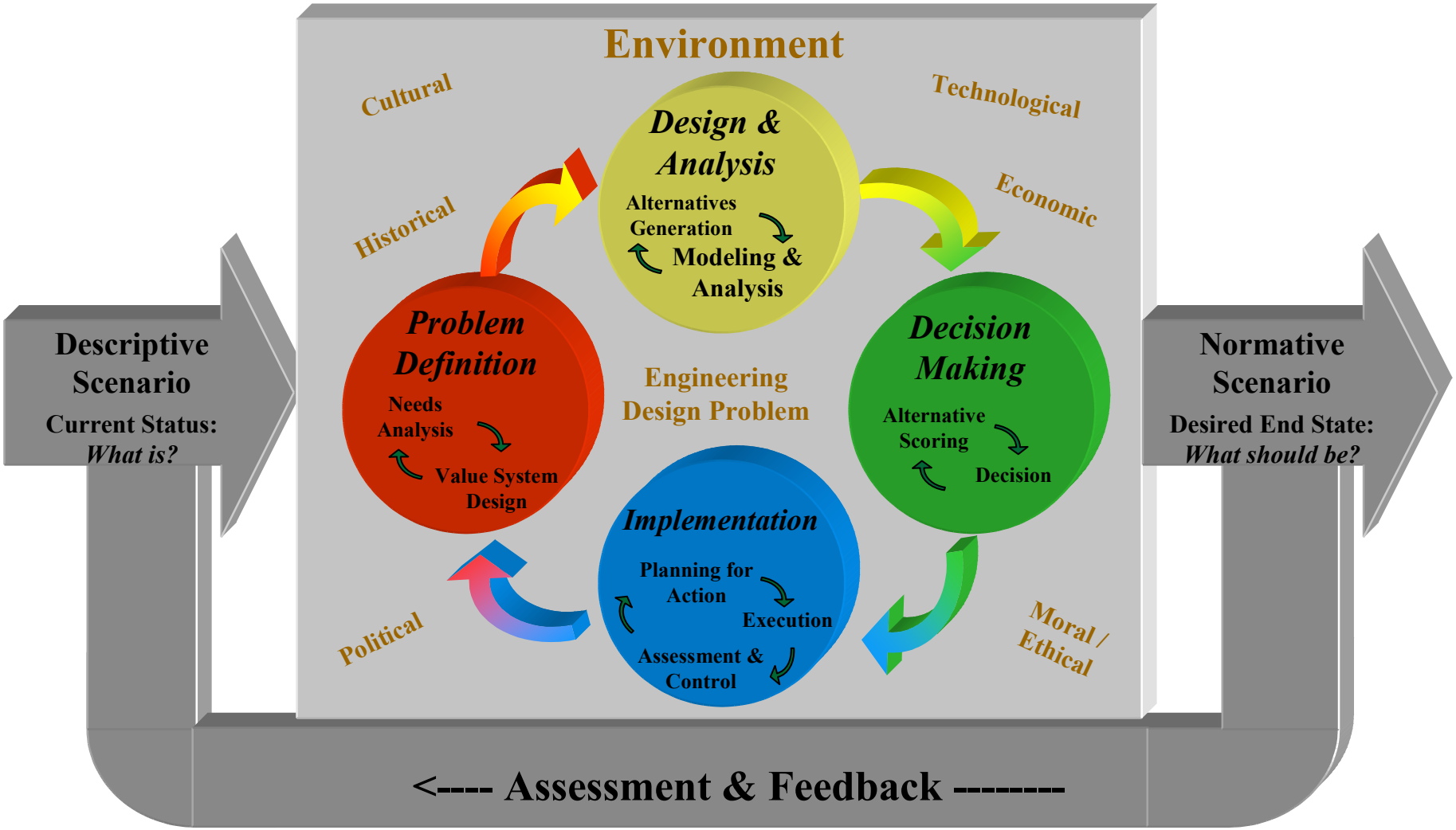
DSE Majors: Class of 2008

Major	Core Courses	Major Courses	Total Courses	Cadets (% of Class)
Systems Engineering *	26	18	44	19 (1.8)
Operations Research	27	15	42	9 (0.8)
Engineering Management *	26	18	44	64 (5.9)
Information Systems Engineering	27	17	44	6 (0.6)
Systems Management	27	13	40	12 (1.1)
Total/Ave	26.2	16.2	42.8	110 (10.2)

*** ABET Accredited**

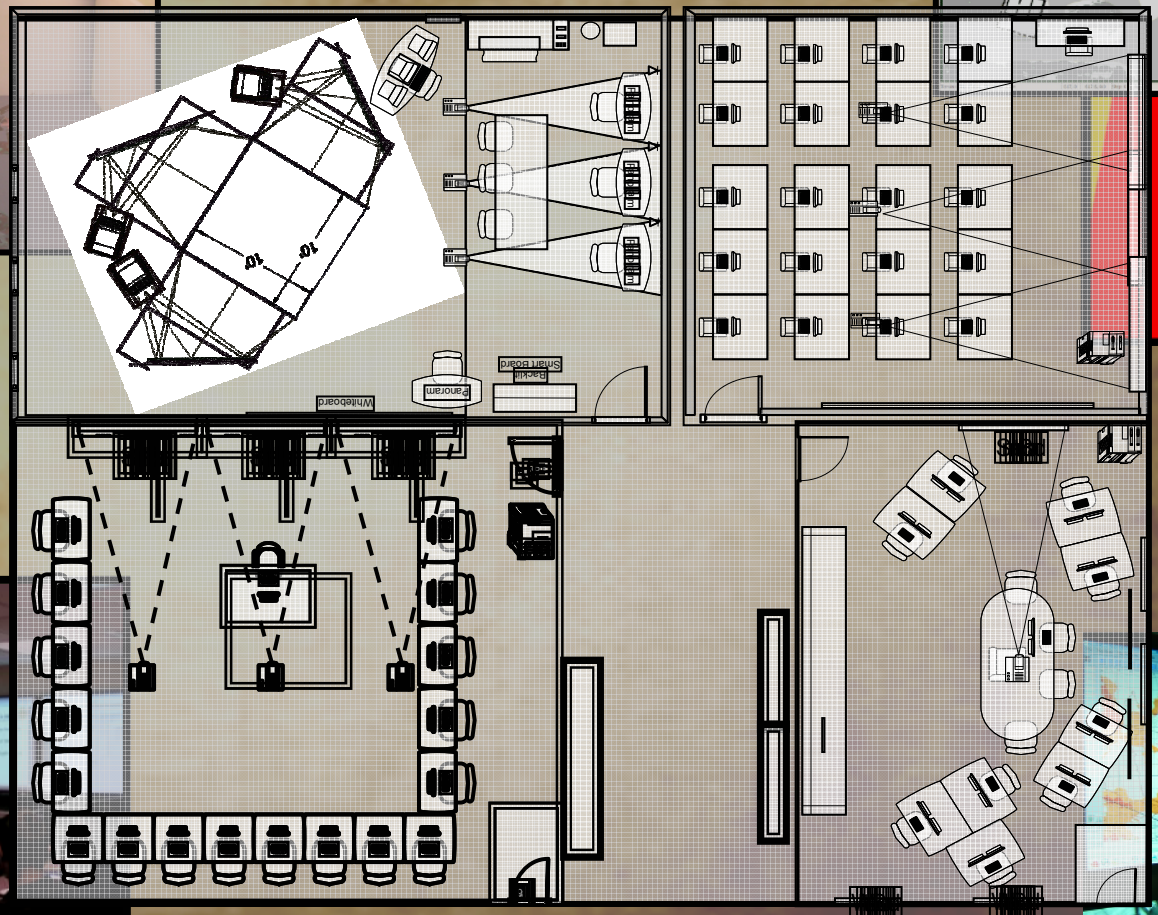
Systems Engineering and Management Process

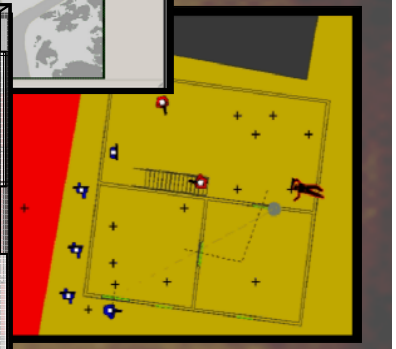


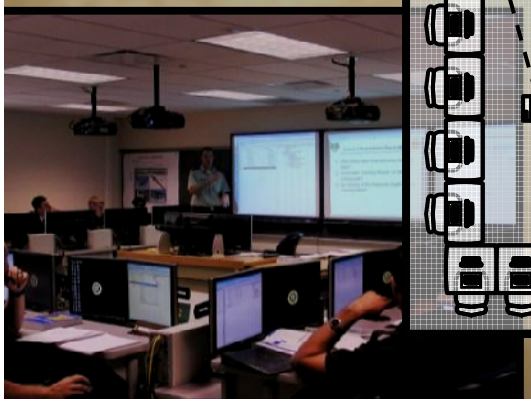
Advanced Individual Academic Development (AIAD)

- Provide Cadets with Systems Engineering, Engineering Management, Information Systems Engineering, Systems Management and Operations Research experience outside a classroom environment
- 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

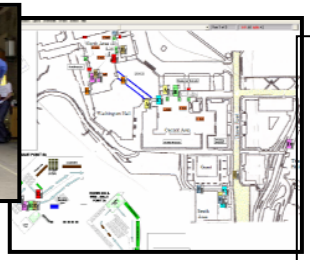
- All capstones are lead by Ph.D.s
- Where possible, AIAD opportunities precede capstones
- Generally 3-5 cadets per capstone team
- Work significant problem with real client for two semesters

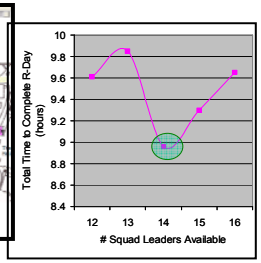
USMA R-Day Design Simulation

- 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

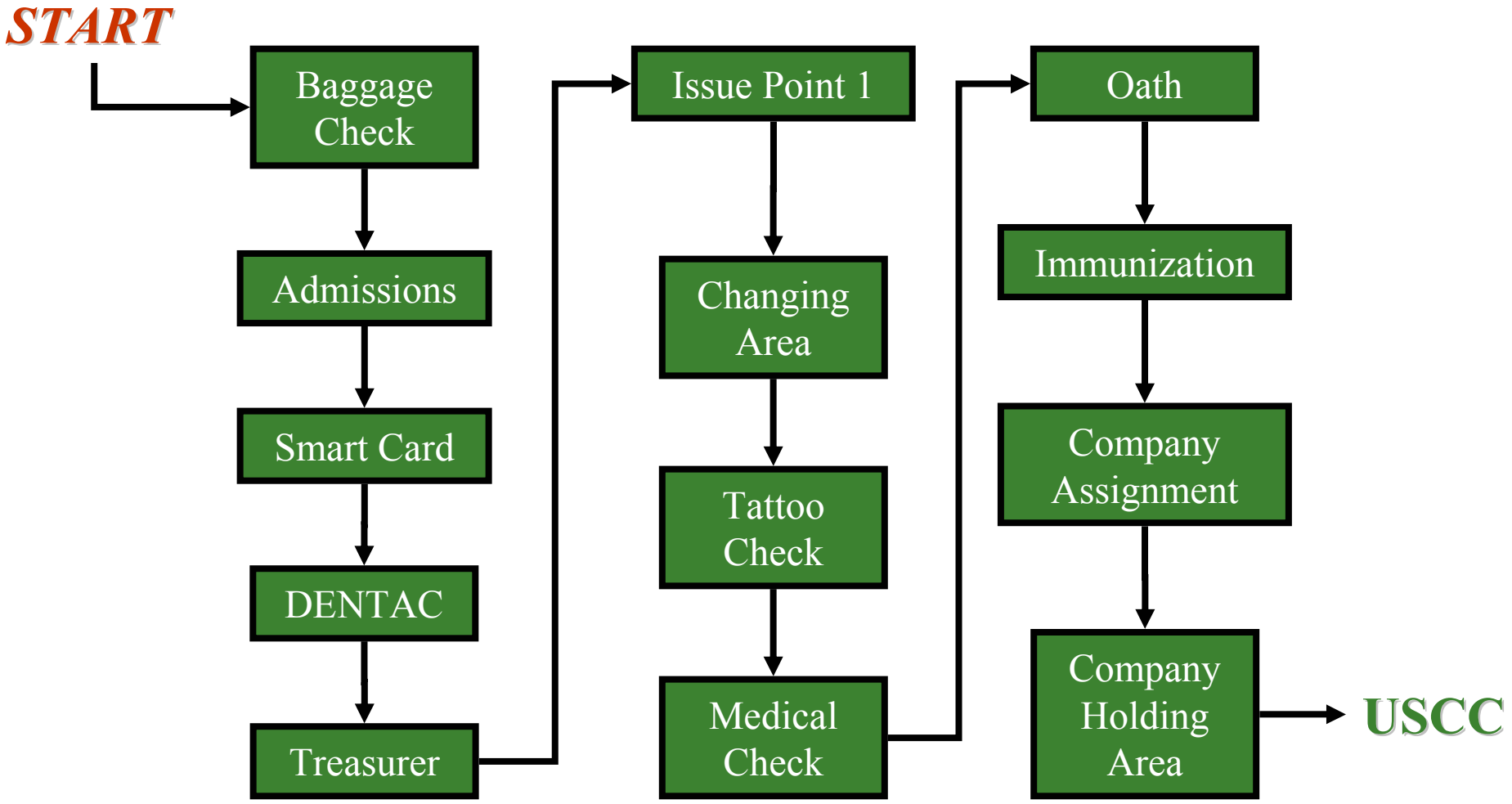
Problem Statement

- 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.

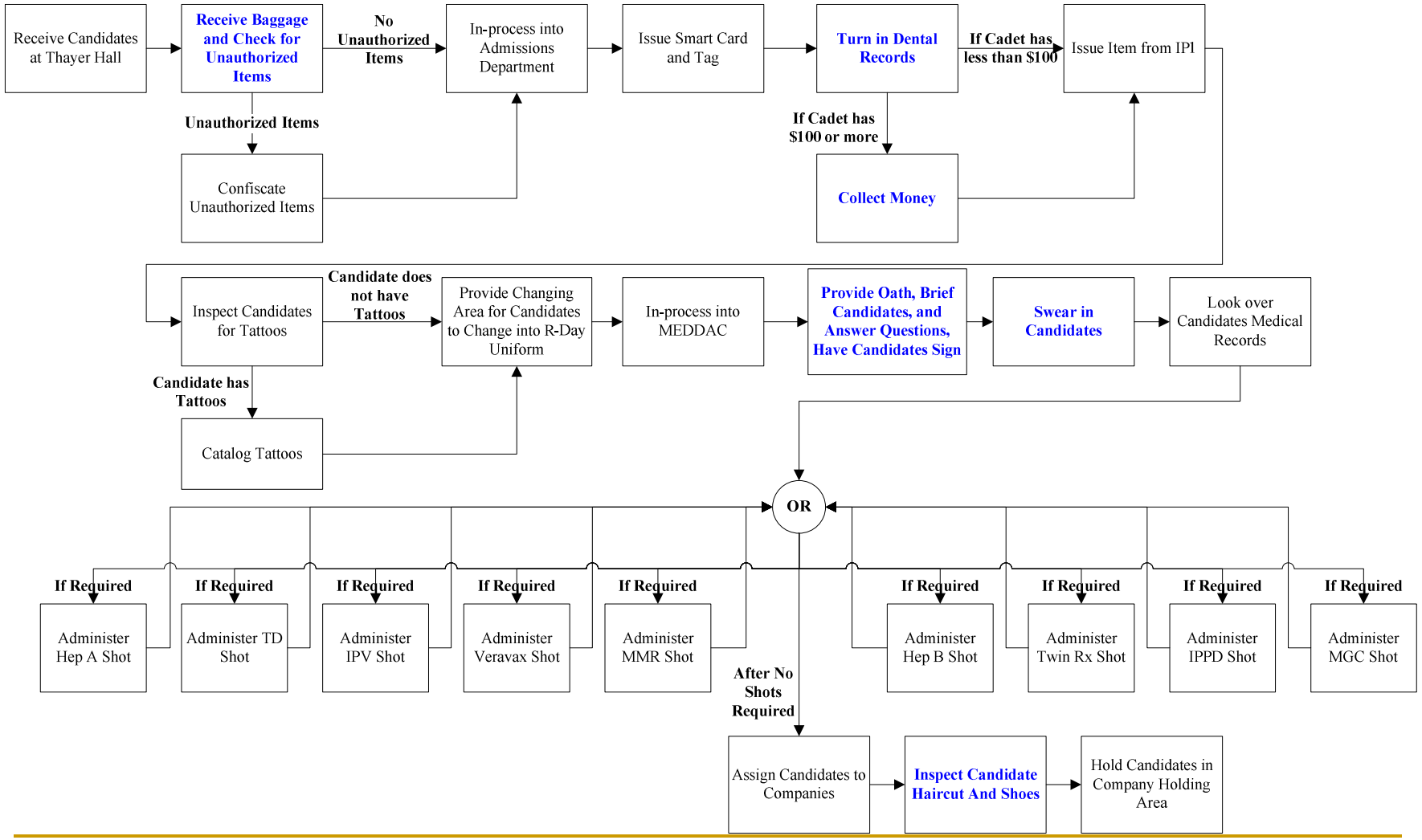
Assumptions

- 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

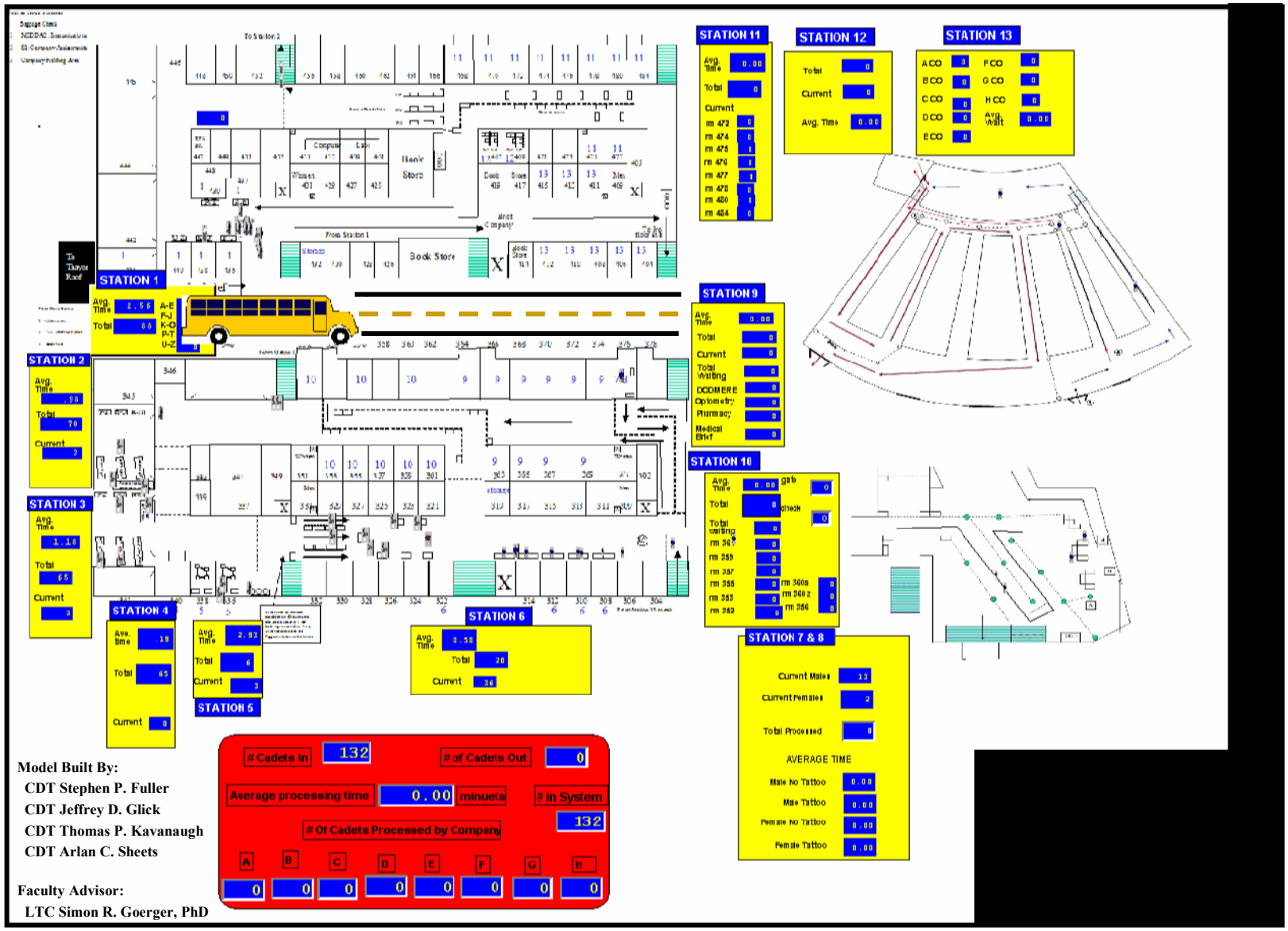
Process Flow: Thayer Hall



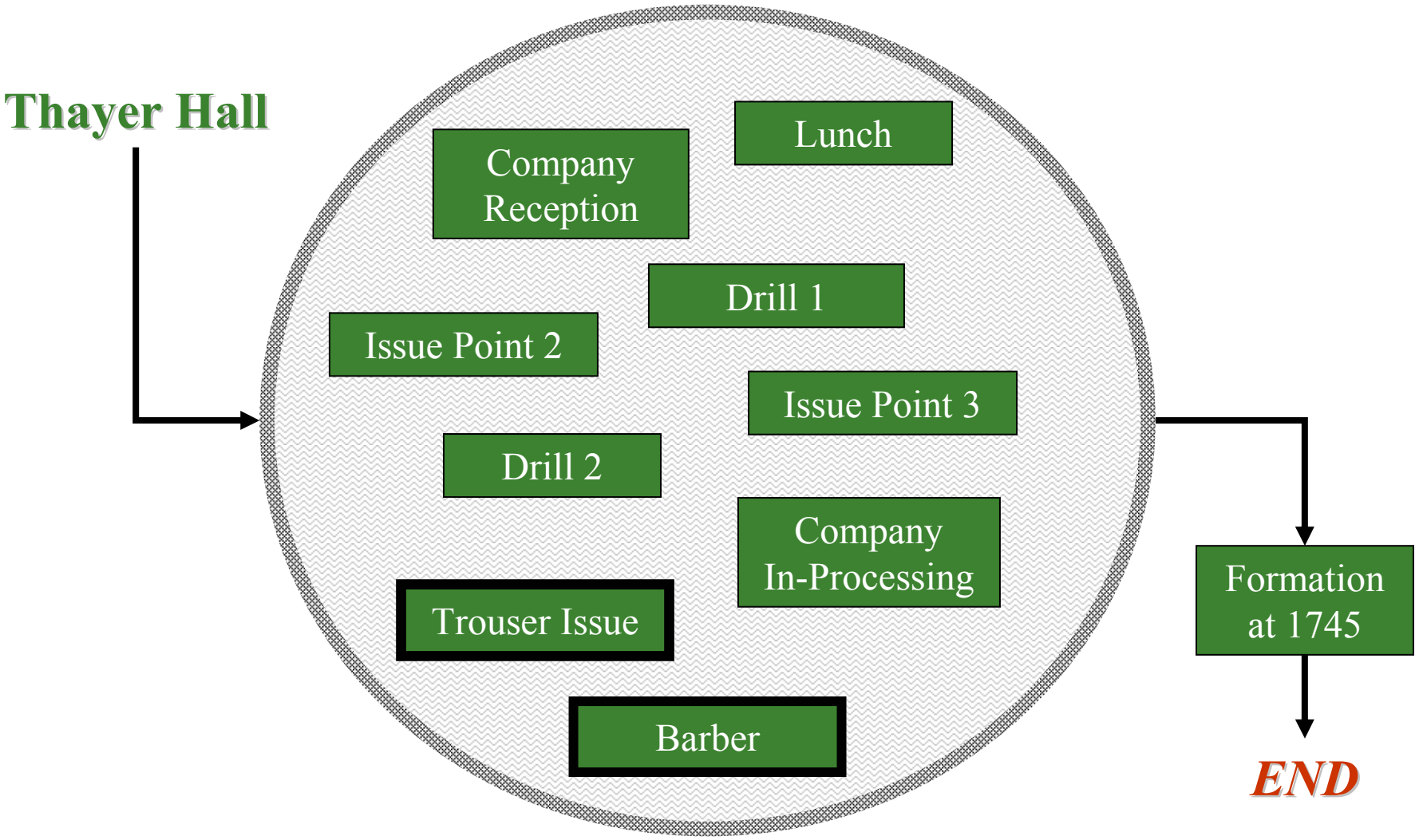
Functional Flow: Thayer Hall



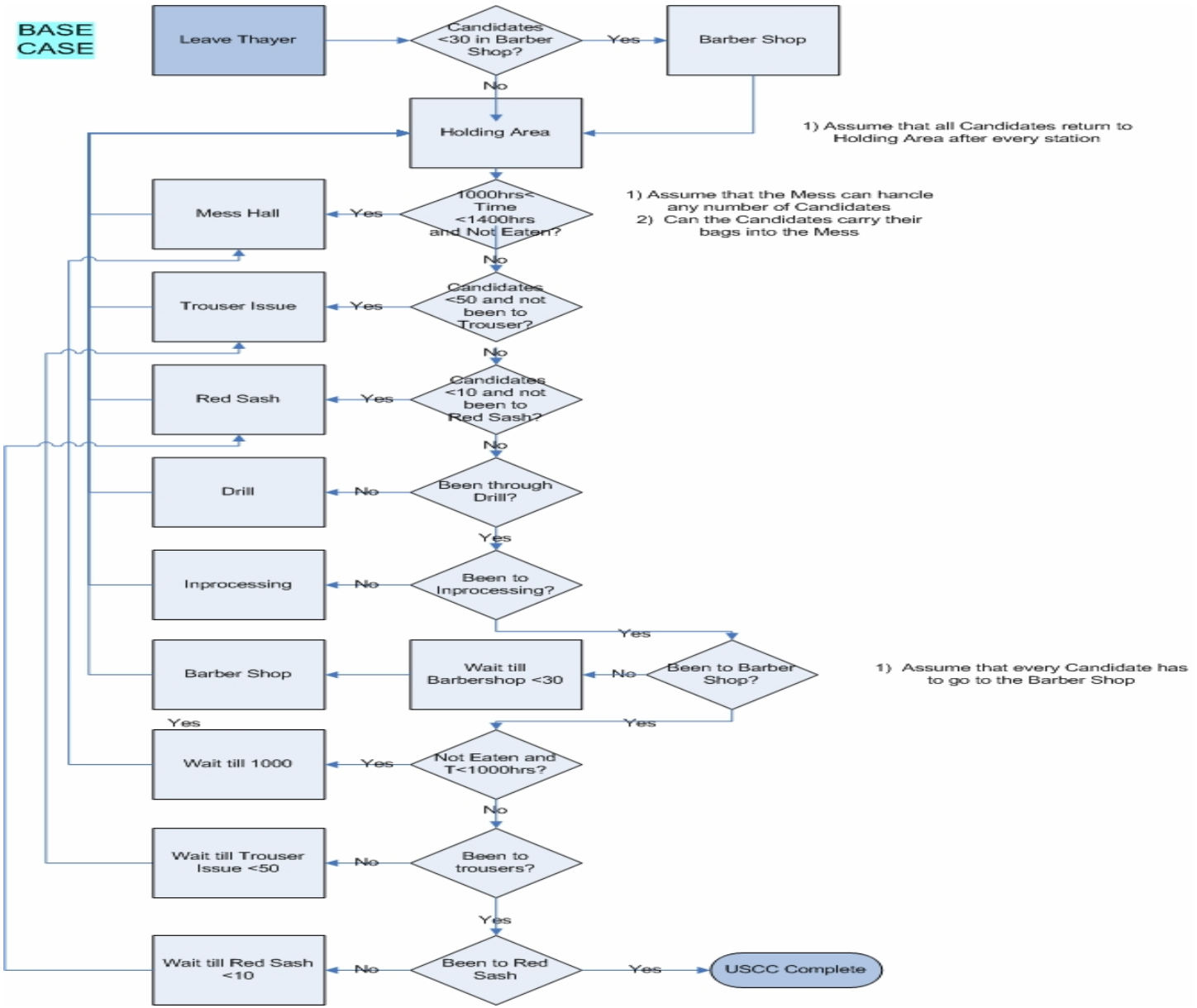
ProModel: Thayer Hall



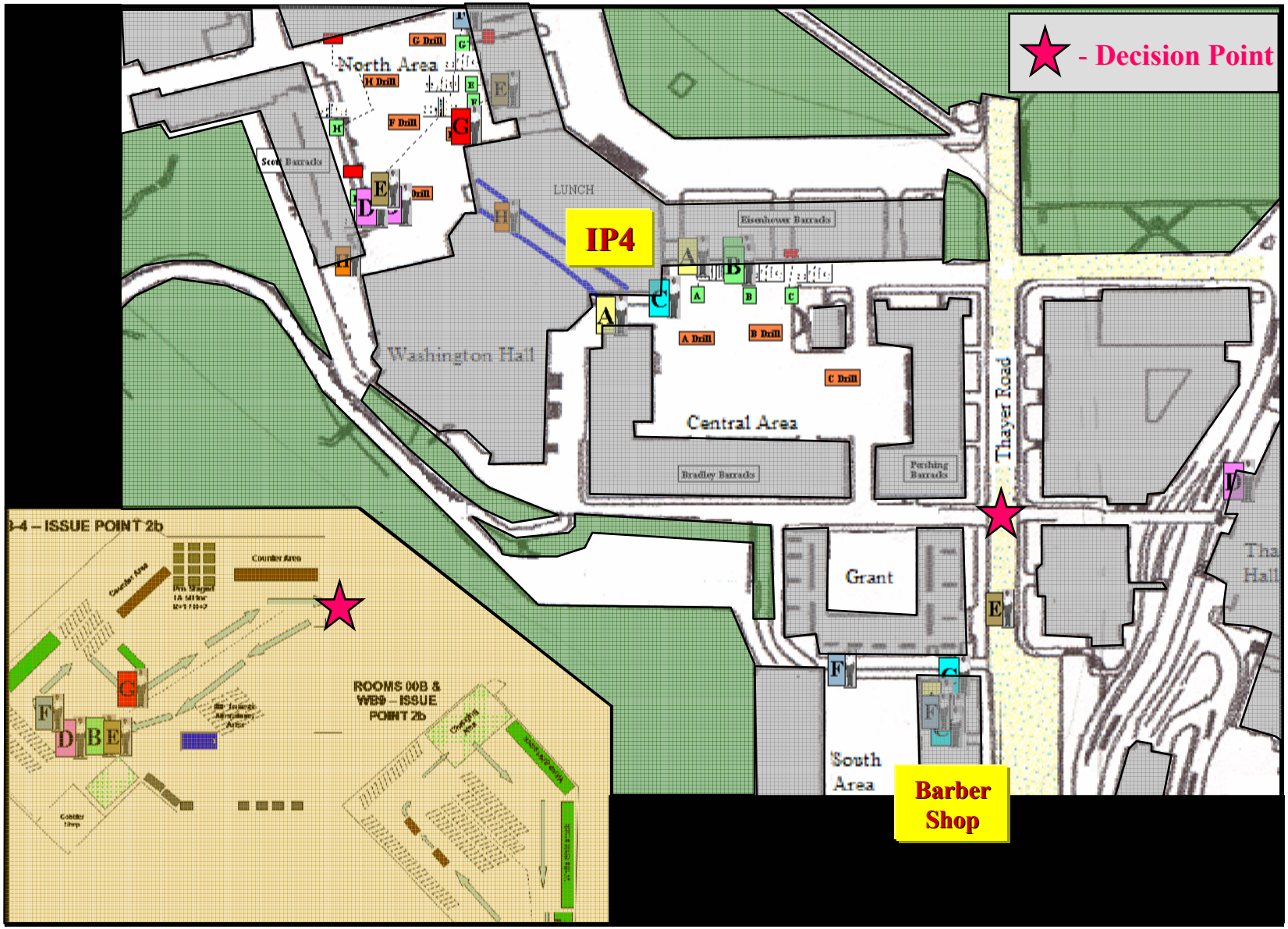
Process Flow: USCC



Functional Flow: USCC



ProModel: USCC



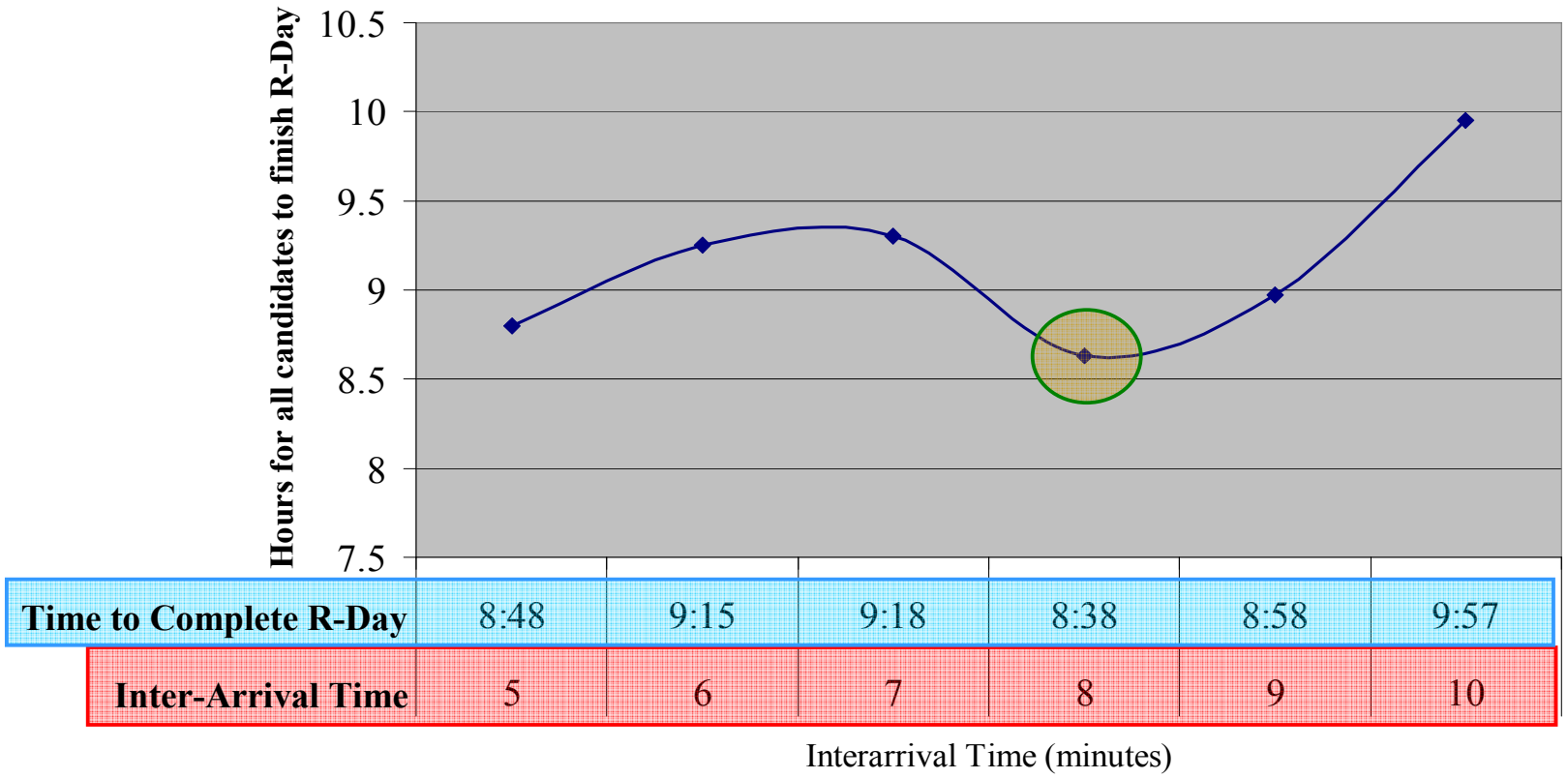
Alternatives/Issues

- 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

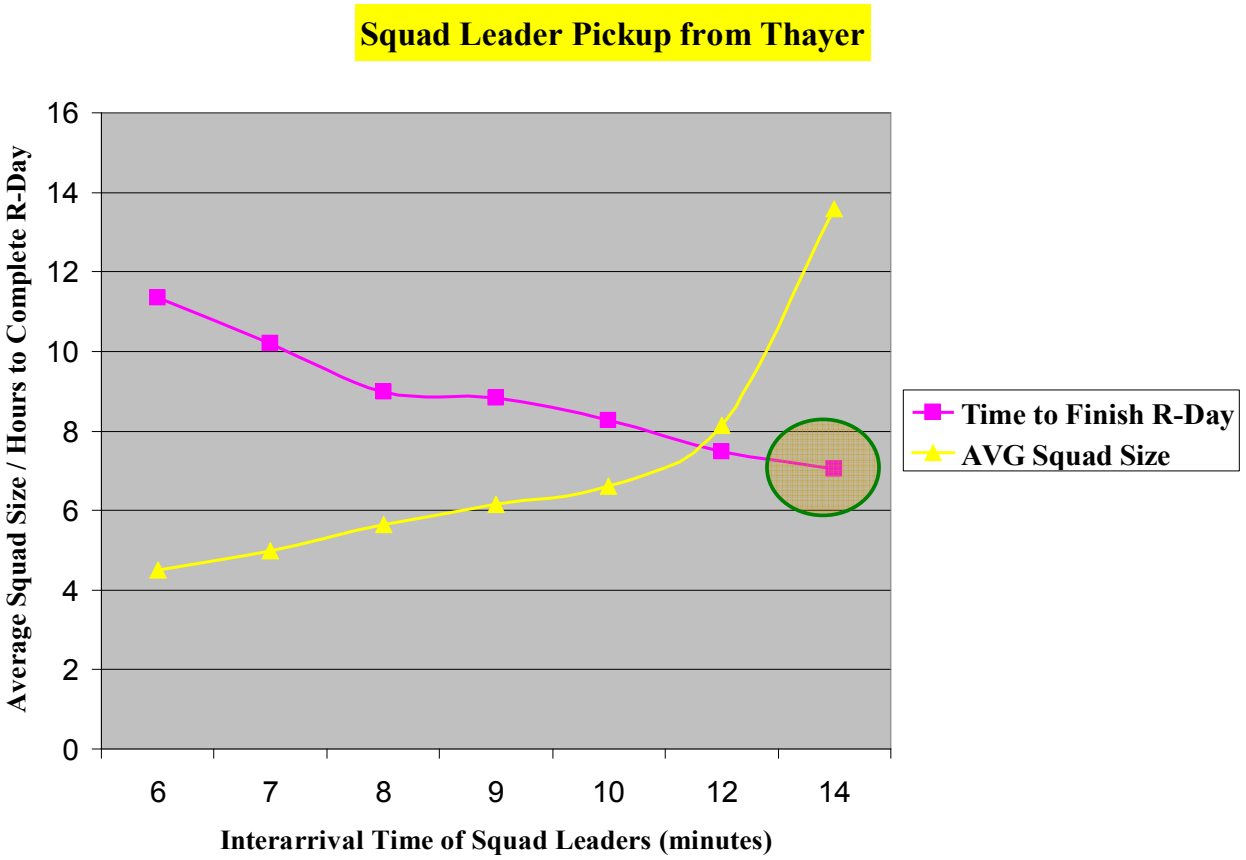
- Arrival rates of busses to Thayer Hall
- ***Bottom Line: Buses should arrive to Thayer Hall approximately every 8:30***

Arrival Times to Thayer



Alternatives

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



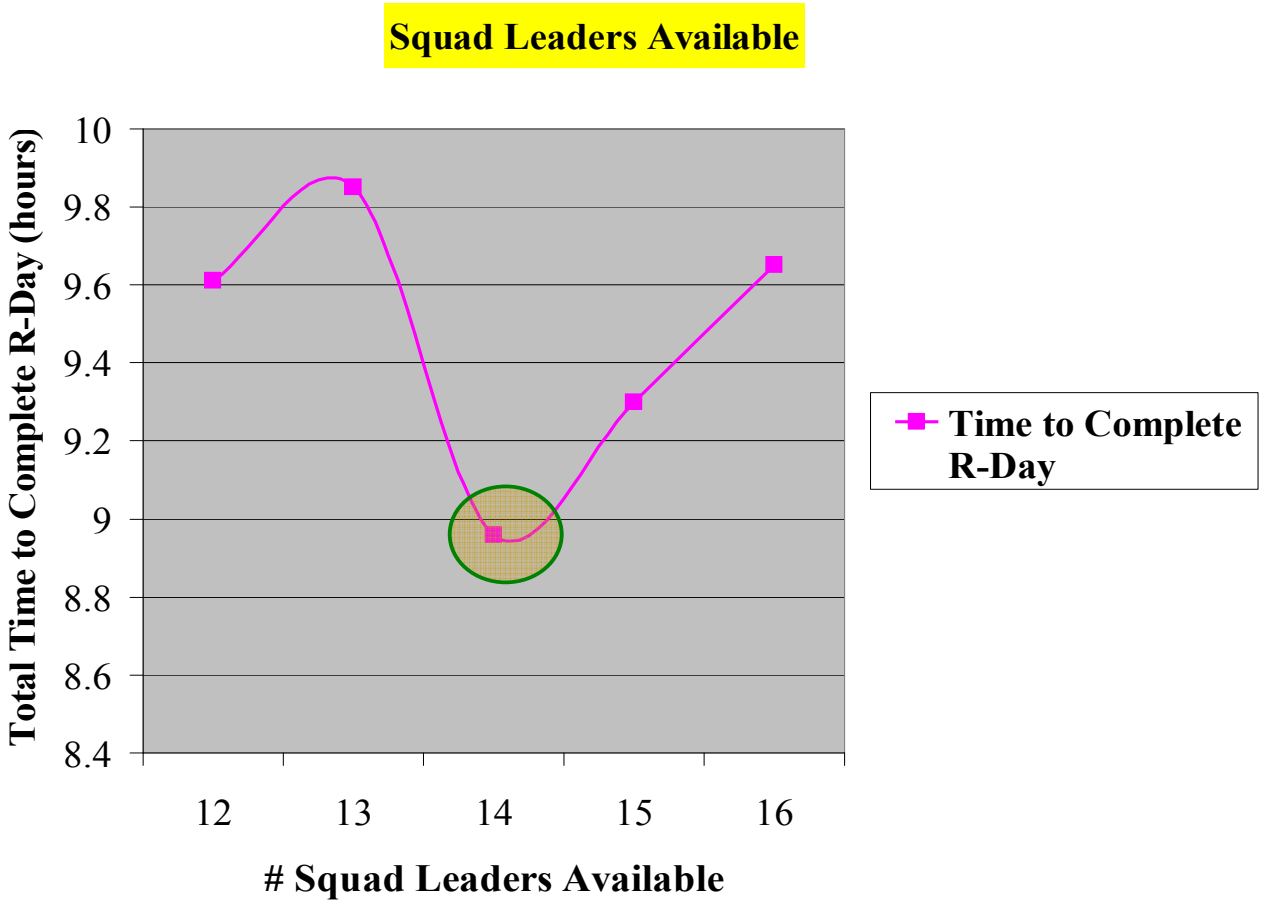
Alternatives

- 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 barber shop when trouser issue still incomplete***

Rule	Time to Complete R-Day
Haircut First	9:02
Trousers First	8:58

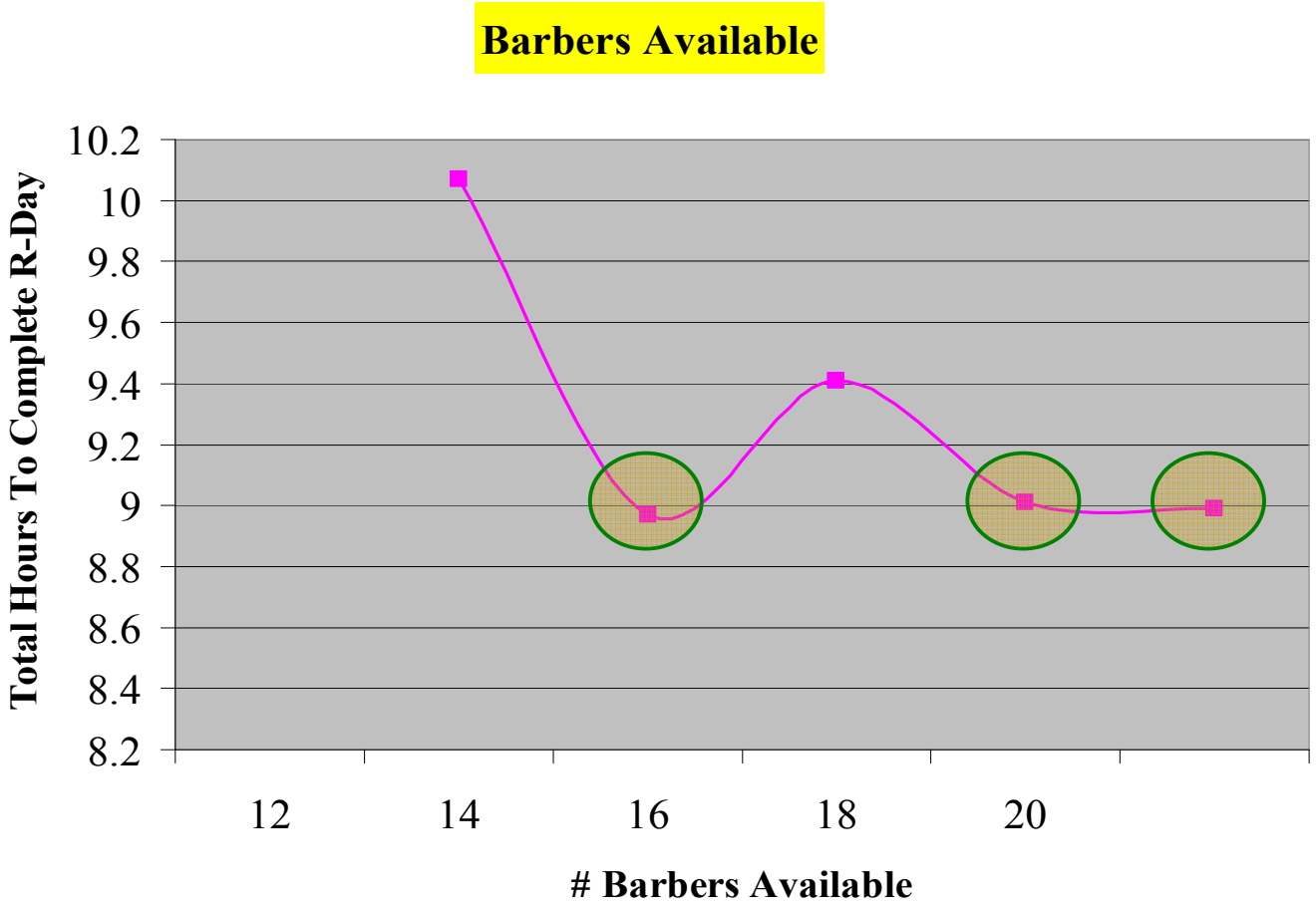
Alternatives

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



Alternatives

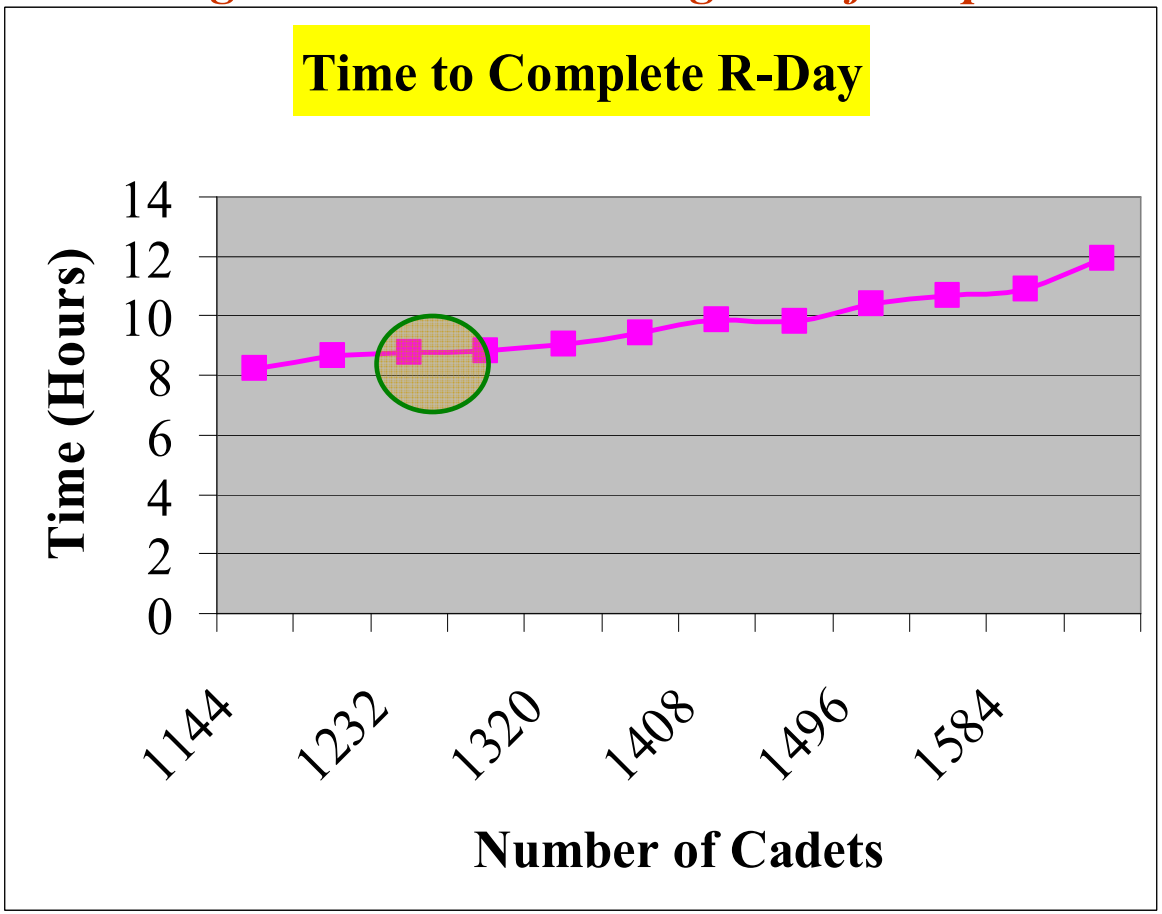
- Vary the number of carbers available
- ***Bottom Line: 16 Barbers cost effective***



Increase the Size of the Corps

Bus Trips	Cadets	Time to Complete R-Day
26	1144	8.25
27	1188	8.68
28	1232	8.78
29	1276	8.8
30	1320	9.05
31	1364	9.45
32	1408	9.85
33	1452	9.83
34	1496	10.42
35	1540	10.65
36	1584	10.9
37	1628	11.95

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



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*)

SimRunner Optimization

- Picked four critical parameters
- Understand the interaction of:
  - Bus Arrival Rates
  - Squad Leader Pick-Up Arrival Rates
  - Squad Leaders Available
  - Barbers Available

SimRunner Optimization Function

x_i = average time at stations 1, 2,…i (a_i is the associated weight for each station)

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

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

x_l = % complete at stations 1, 2,…l (d_l is the associated weight for each station)

x_m = total throughput of the simulation (e_m is the associated weight for each station)

SimRunner Optimization Function

- 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

Bus Arrival Rates (Min)	Squad Leader Pick-Up Arrival Rates (Min)	Number of Squad Leaders Available (per Company)	Number of Available Barbers	Objective Function
7	14	13	12	27248.613
7	14	15	12	27248.613
7	14	14	12	27248.613
6	14	15	12	27245.455
6	14	14	12	27245.455
6	14	13	12	27222.004
6	14	12	12	27168.011
9	14	12	12	27116.028
8	14	12	12	27077.671
8	14	13	12	27077.671

SimRunner Optimization Results

Method	Bus Arrival Rates (Min)	Squad Leader Pick-Up Arrival Rates (Min)	Number of Squad Leaders Available (per Company)	Number of Available Barbers
Four Factor Optimization	7	14	13	12
One Factor Optimization	8	14	14	16
Actual for 2004	~9	~10	Average 13	Average 14
Actual for 2005	~8	~15	Average 13	Average 14

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 students completing the DSE Program.

Questions

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