Term End Exam Scheduling at USMA, West Point

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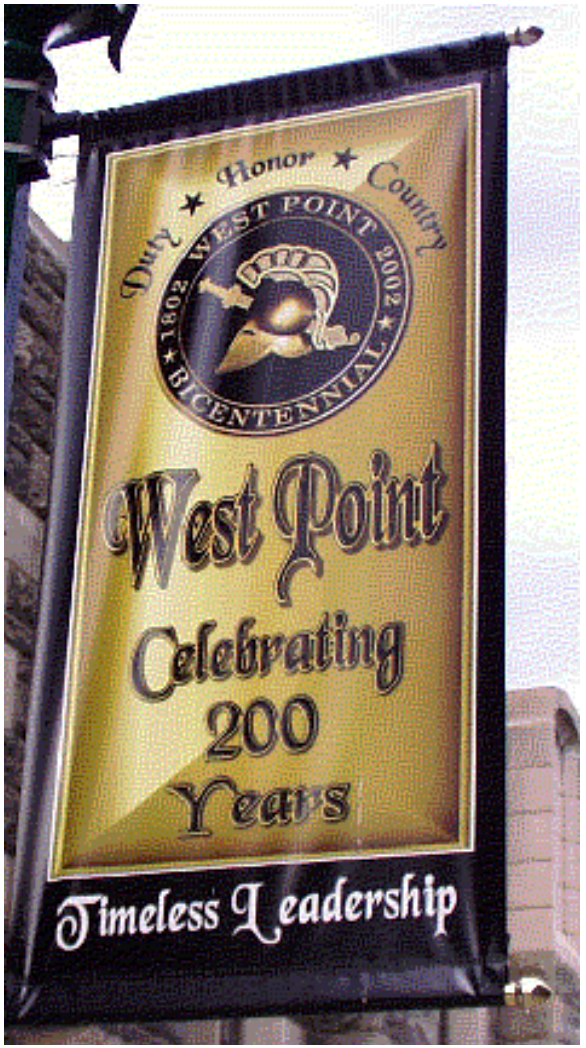
USMA Mission

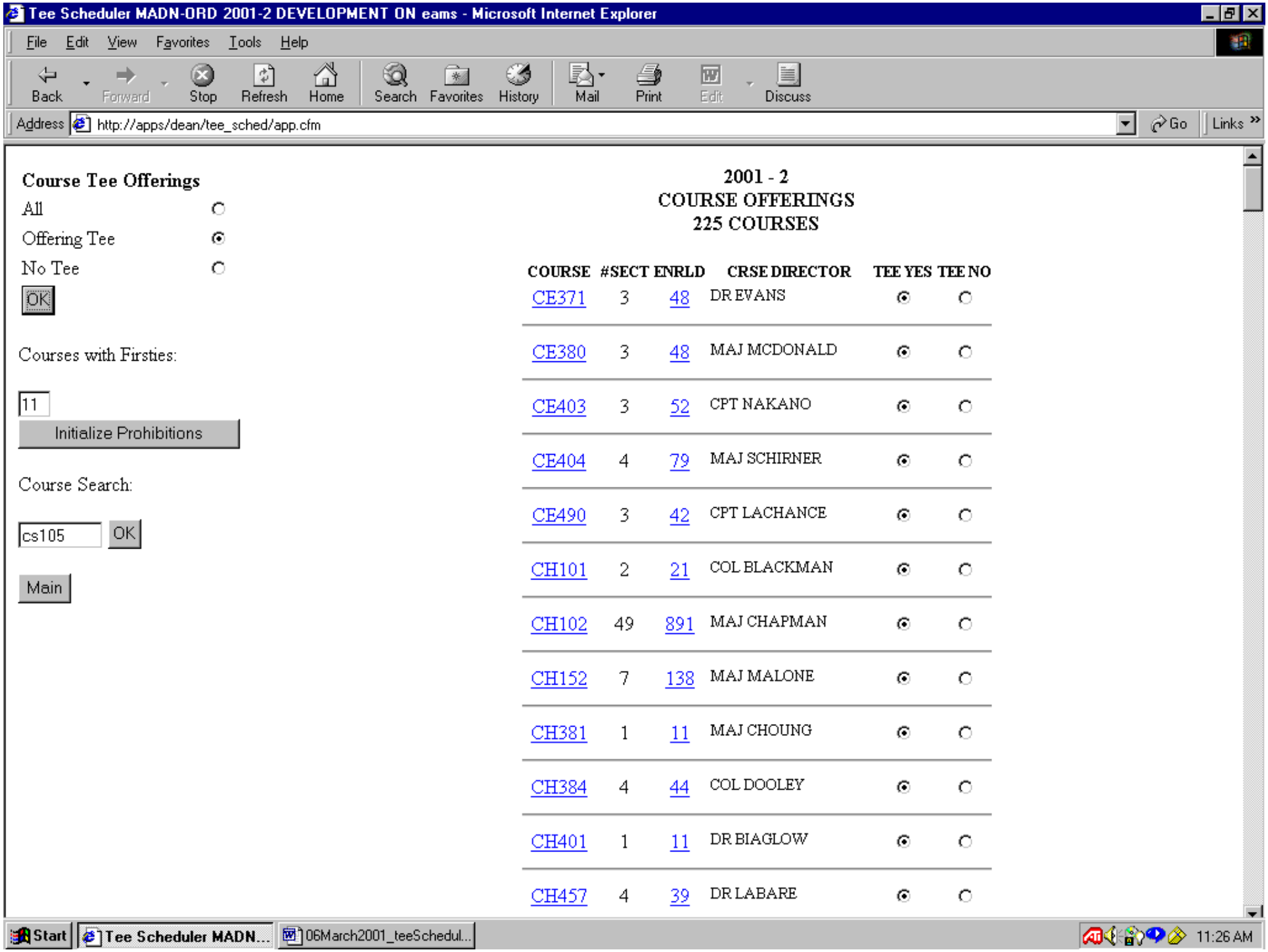
To educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country; professional competence throughout a career as an officer of the United States Army; and a lifetime of selfless service to the nation.

Exams



Academic Scheduling

- Term end exam (TEE) scheduling
  - Scheduling preparation
  - Find *good* schedules for exam courses **and** cadets.
  - Post scheduling
- Course scheduling
  - For a given set of *course offerings* find *good* schedules for all cadets.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Go Links
Course Tee Offerings
All
Offering Tee
No Tee
OK
Courses with Firsties:
11
Initialize Prohibitions
Course Search:
cs105
OK
Main
2001 - 2
COURSE OFFERINGS
225 COURSES
COURSE #SECT ENRLD CRSE DIRECTOR TEE YES TEE NO
CE371 3 48 DR EVANS
CE380 3 48 MAJ MCDONALD
CE403 3 52 CPT NAKANO
CE404 4 79 MAJ SCHIRNER
CE490 3 42 CPT LACHANCE
CH101 2 21 COL BLACKMAN
CH102 49 891 MAJ CHAPMAN
CH152 7 138 MAJ MALONE
CH381 1 11 MAJ CHOUNG
CH384 4 44 COL DOOLEY
CH401 1 11 DR BIAGLOW
CH457 4 39 DR LABARE
Start
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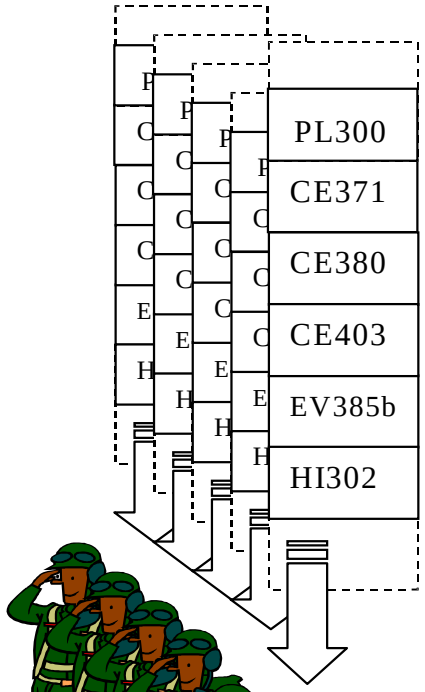
Set Acad Year | Set Periods | Main

2001 - 2 TEE PERIODS

Year	Term	Date	Period	Start Time	End Time
2001	2	05/21/01	1	0735	1105
2001	2	05/21/01	3	0735	1105
2001	2	05/21/01	2	1500	1830
2001	2	05/22/01	5	0735	1105
2001	2	05/22/01	4	1500	1830
2001	2	05/23/01	6	1500	1830
2001	2	05/24/01	7	0735	1105
2001	2	05/24/01	8	1500	1830
2001	2	05/25/01	9	0735	1105
2001	2	05/25/01	10	1500	1830
2001	2	05/26/01	11	0735	1105
2001	2	05/26/01	12	1500	1830

Term End Exam Scheduling

	1	2		6
morning period	CE371 CH384 CS383 HI366	CH101 CS408 EE301 EN302		EV203 PH203 PL300 LR204
afternoon period	CE404 LG484 LS362 MS350	LF382 SE388 SS388 …		CE403 CS380 SS201 …



Term End Exam Courses (≈250 courses)

≈ 4000 cadets

≈20000 exams

Overcoming Conflicts

- Schedule with conflicts

1	2		6
CE371 CH384 CS383 HI366	CH101 CS408 EE301 EN302		EV203 PH203 PL300 LR204
CE404 LG484 LS362 MS350	LF382 SE388 SS388 CE403		CE403 CS380 SS201 …

Cadet's 8TAP:

PL300
CE372
CE403
CS380
EV180
HI302

- Makeup/ahead for an exam course:
  - An additional exam offering for a small group of cadets who can not go to the primary exam offering
- Resolve conflicts by adding makeup/ahead

TEE Scheduling

- Given exam courses
  - `MA481  CE371  CH100  ...`
- Given exam periods
  - `p1, p2, p3, ... p12`
- Given cadet's exam course '*requests*'
  - `043671571,CE403`
  - `043671571,CE380`
- Find an assignment of exam course sessions (primaries, makeups) to periods and cadet's requests to exam courses sessions.
  - `CE403,prim,p12  CE403,mkup,p4  CE380,prim,p4 ...`
  - `043671571,CE403,p4  043671571,CE380,p4  ...`
- Objective: Minimize the total number of makeups

TEE Constraints

- No conflicts (no cadet in more than one exam sessions per period) `(Conflict)`
- All exam courses and all exam requests must be assigned `(Assign)`
- Parts of the exam session schedule (i.e. fixed periods for some primaries) may be given `(Fixed)`
- Primary exam session enrollment minimum (e.g. 75%) `(PrimEnroll)`
- Certain periods are prohibited for certain exam courses. `(Prohibited)`

More TEE Constraints

- Inclusive/Exclusive groups
  - Some primaries must be scheduled together (`Inclusive`)
  - Some exam courses must be scheduled apart (`Exclusive`)
- Courses with no makeups allowed (`No makeups`)
- Plebe/Firsties constraints
  - One exam a day for Plebes (`Exams per day`)
  - Exam period is over by period X for Firsties (`Finished`)
- Consecutive (back to back) exam limit (`Consecutive`)
- Produce schedules in a timely fashion

An Optimization Model

- Variables
  - `x(c,r,p)` cadet request to course/period **250.000**
  - `y(r,s,p)` course session to period **|S|*3.000**
  - `z(r,p)` primary indicator **3.000**
- Constraints
  - `Conflict` **50.000**
  - `Assign` **20.000**
  - `PrimEnroll` $\sum_c x(c,r,p) \geq 0.75 \cdot enroll(r) \cdot z(r,p), \sum_p z(r,p) = 1$ **3.250**
  - `Consecutive` **36.000**
  - `Exams per day` **6.000**
  - `Inclusive` **|I|*12**
  - `Exclusive` **|S||I|*12**
  - `Fixed,Prohibit,No makeup,Finished` by variable fixing
  - Coupling of `x` and `y` $\sum_c x(c,r,p) \leq enroll(r) \cdot y(r,s,p)$ **|S|*3.000**

Analysis of this Model

- `Consecutive` Constraint is a headache
  - Many constraints, lots of non zeros
  - 'Unimportant' constraint

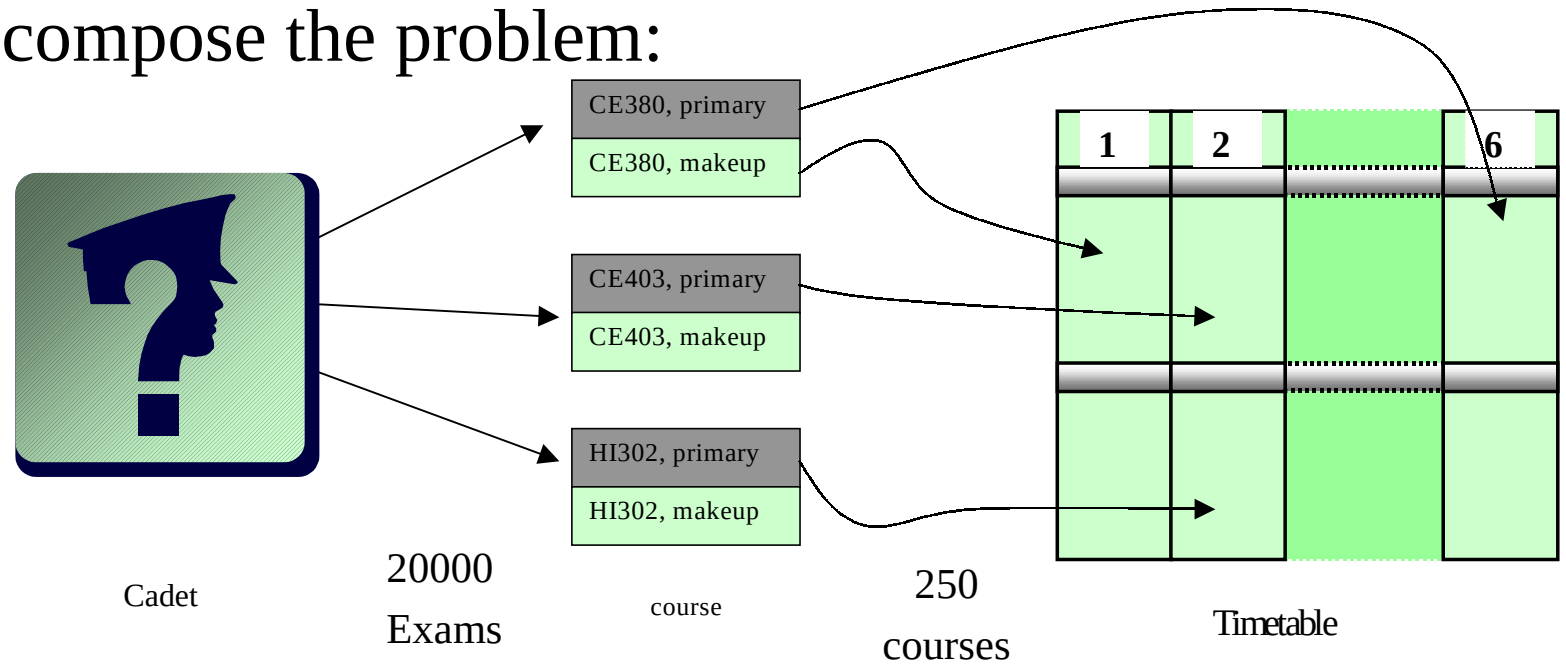
    → drop `Consecutive` constraint from model
- Problem is large
- Problem is (integer) infeasible
- Model with penalized violations expensive
  - CPLEX 7.1 doesn't find any integer solution for a feasible model within 24h on a 1GHz PC
  - CPLEX 7.1 doesn't improve a given bad integer solution (using **`mipstart`**) within 24h on a 1GHz PC

Solution Approach

- Heuristic based on a collection of medium sized optimization models produces conflict free schedules and automatically relaxes constraints.
- Improvement module starts with a good/ mediocre solution and a set of relaxed constraints and tries to
  - Improve number of makeups
  - Reinforce relaxed constraints

Solution Improvement

- Given a solution
  - Assignment of exam courses (primary and makeup) to periods
  - Assignment of cadets to periods
  - Set of relaxed constraints
- Decompose the problem:



Improvement Model 1

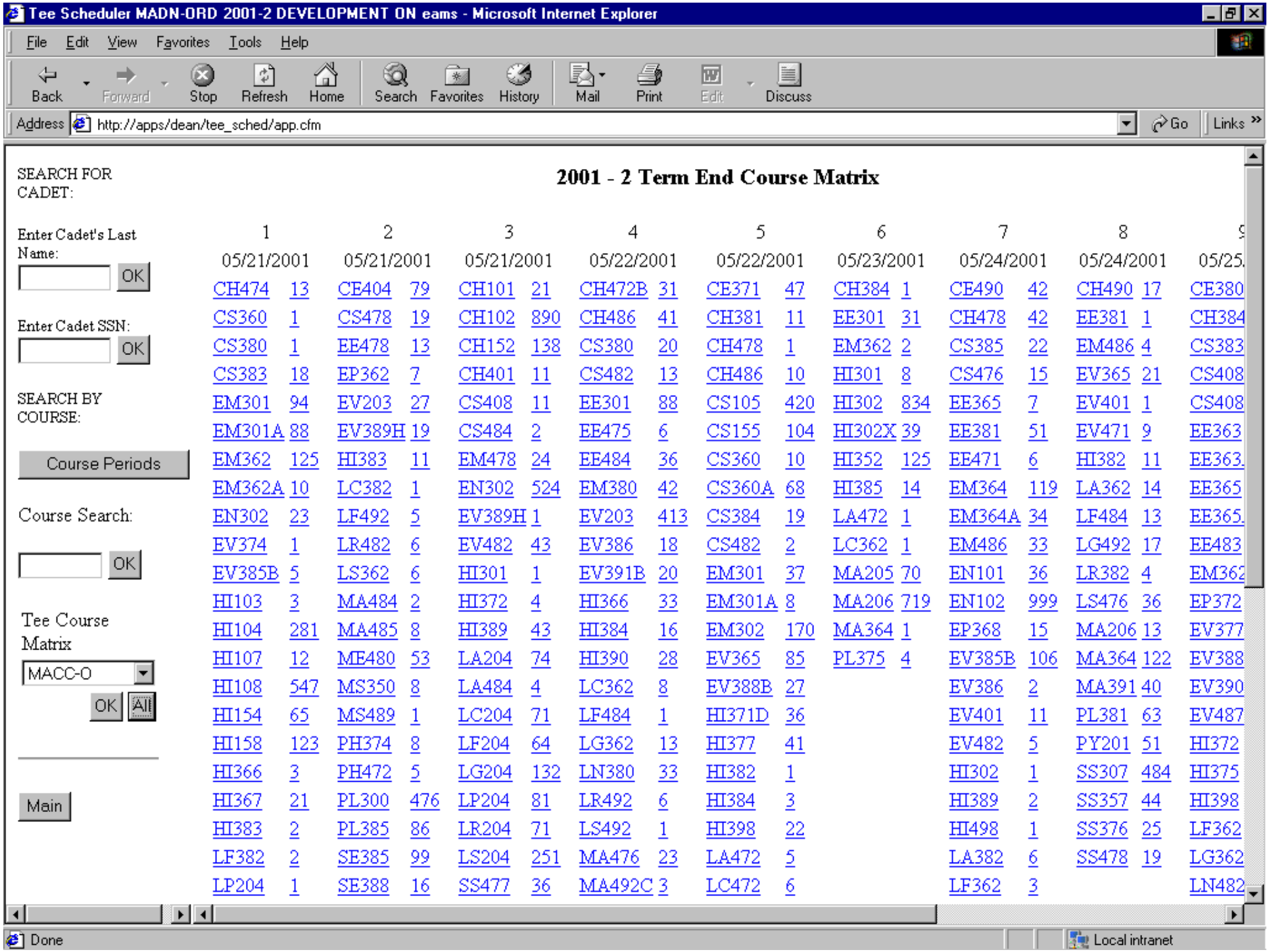
- Fixed assignment of cadet request to exam course session
  - Variable transformation `x(c,r,p) ~ x(c,r,s)`
- Variables
  - `w(r,p)` open period for course session **3.000**
  - `y(r,s,p)` course session to period **|S'|*3.000**
- Constraints
  - `Conflict` $\sum_{r,s} y(r,s,p) \le 1$ **50.000**
  - `Exams per day` **6.000**
  - `Inclusive/Exclusive` **(1+|S'|)|I|*12**
  - `Fixed,Prohibit,No makeup,Finished` by variable fixing
  - Coupling of `w` and `y` **3.000**
- Objective $y(r,s,p) \le w(r,p)$
  - `Min sum((r,p),w(r,p))` (folds sessions of the same course)
  - `Min` violations of relaxed constraints

Improvement Model 2

- Fixed assignment of exam sessions to periods
- Variables
  - `x(c,r,s)` cadet request to course session **250.000**
  - `y(r,s,p)` course session open **|S'|+250**
- Constraints
  - `Conflict` **20.000+a(S')**
  - `Exams per day` **6.000**
  - `Finished` by variable fixing
  - Coupling of `x` and `y` **|S'|+250**
- Objective
  - `Min sum((r,s,p),y(r,s,p)) + enrollment in makeup`
    (closes some sessions and reduces enrollment in makeup)

Improvement Algorithm

- The model 1 and 2 are iteratively repeated
- Model 1 requires a good/mediocre solution
  - Size and running time depend on number of makeups in the initial solution (need heuristic)
- The different cadet/session assignment makes new course/period assignment likely and vice versa.
  - The constraint reinforcing objective shocks the system if it is stuck
- Terminates when out of time (user input) or shocking doesn’t help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File Edit View Favorites Tools Help
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Address http://apps/dean/tee_sched/app.cfm
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SEARCH FOR CADET:
Enter Cadet's Last Name:
OK
Enter Cadet SSN:
OK
SEARCH BY COURSE:
Course Periods
Course Search:
OK
Tee Course Matrix
MACC-O
OK All
Main
2001 - 2 Term End Course Matrix
1 05/21/2001
CH474 13
CS360 1
CS380 1
CS383 18
EM301 94
EM301A 88
EM362 125
EM362A 10
EN302 23
EV374 1
EV385B 5
HI103 3
HI104 281
HI107 12
HI108 547
HI154 65
HI158 123
HI366 3
HI367 21
HI383 2
LF382 2
LP204 1
2 05/21/2001
CE404 79
CS478 19
EE478 13
EP362 7
EV203 27
EV389H 19
HI383 11
LC382 1
LF492 5
LR482 6
LS362 6
MA484 2
MA485 8
ME480 53
MS350 8
MS489 1
PH374 8
PH472 5
PL300 476
PL385 86
SE385 99
SE388 16
3 05/21/2001
CH101 21
CH102 890
CH152 138
CH401 11
CS408 11
CS484 2
EM478 24
EN302 524
EV389H 1
EV482 43
HI301 1
HI372 4
HI389 43
LA204 74
LA484 4
LC204 71
LF204 64
LG204 132
LP204 81
LR204 71
LS204 251
SS477 36
4 05/22/2001
CH472B 31
CH486 41
CS380 20
CS482 13
EE301 88
EE475 6
EE484 36
EM380 42
EV203 413
EV386 18
EV391B 20
HI366 33
HI384 16
HI390 28
LC362 8
LF484 1
LG362 13
LN380 33
LR492 6
LS492 1
MA476 23
MA492C 3
5 05/22/2001
CE371 47
CH381 11
CH478 1
CH486 10
CS105 420
CS155 104
CS360 10
CS360A 68
CS384 19
CS482 2
EM301 37
EM301A 8
EM302 170
EV365 85
EV388B 27
HI371D 36
HI377 41
HI382 1
HI384 3
HI398 22
LA472 5
LC472 6
6 05/23/2001
CH384 1
EE301 31
EM362 2
HI301 8
HI302 834
HI302X 39
HI352 125
HI385 14
LA472 1
LC362 1
MA205 70
MA206 719
MA364 1
PL375 4
7 05/24/2001
CE490 42
CH478 42
CS385 22
CS476 15
EE365 7
EE381 51
EE471 6
EM364 119
EM364A 34
EM486 33
EN101 36
EN102 999
EP368 15
EV385B 106
EV386 2
EV401 11
EV482 5
HI302 1
HI389 2
HI498 1
LA382 6
LF362 3
8 05/24/2001
CH490 17
EE381 1
EM486 4
EV365 21
EV401 1
EV471 9
HI382 11
LA362 14
LF484 13
LG492 17
LR382 4
LS476 36
MA206 13
MA364 122
MA391 40
PL381 63
PY201 51
SS307 484
SS357 44
SS376 25
SS478 19
9 05/25.
CE380
CH384
CS383
CS408
CS408
EE363
EE363.
EE365
EE365.
EE483
EM362
EP372
EV377
EV388
EV390
EV487
HI372
HI375
HI398
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LG362
LN482
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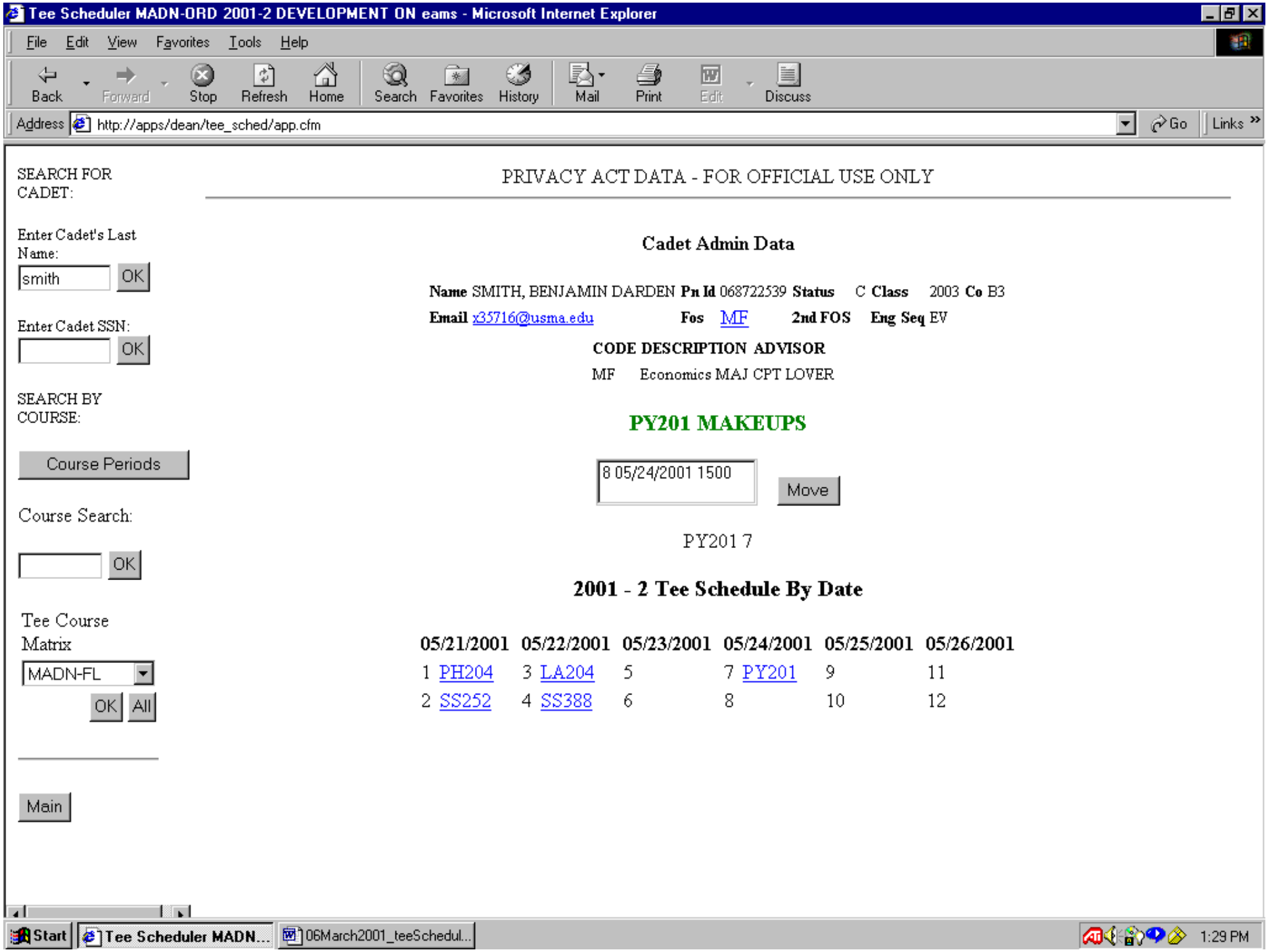
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Go Links
SEARCH FOR CADET:
Enter Cadet's Last Name:
smith
OK
Enter Cadet SSN:
OK
SEARCH BY COURSE:
Course Periods
Course Search:
OK
Tee Course Matrix
MADN-FL
OK All
Main
PRIVACY ACT DATA - FOR OFFICIAL USE ONLY
Cadet Admin Data
Name SMITH, BENJAMIN DARDEN Pn Id 068722539 Status C Class 2003 Co B3
Email x35716@usma.edu Fos MF 2nd FOS Eng Seq EV
CODE DESCRIPTION ADVISOR
MF Economics MAJ CPT LOVER
PY201 MAKEUPS
8 05/24/2001 1500
Move
PY201 7
2001 - 2 Tee Schedule By Date
05/21/2001 05/22/2001 05/23/2001 05/24/2001 05/25/2001 05/26/2001
1 PH204 3 LA204 5 7 PY201 9 11
2 SS252 4 SS388 6 8 10 12
Start
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Feasibility Study

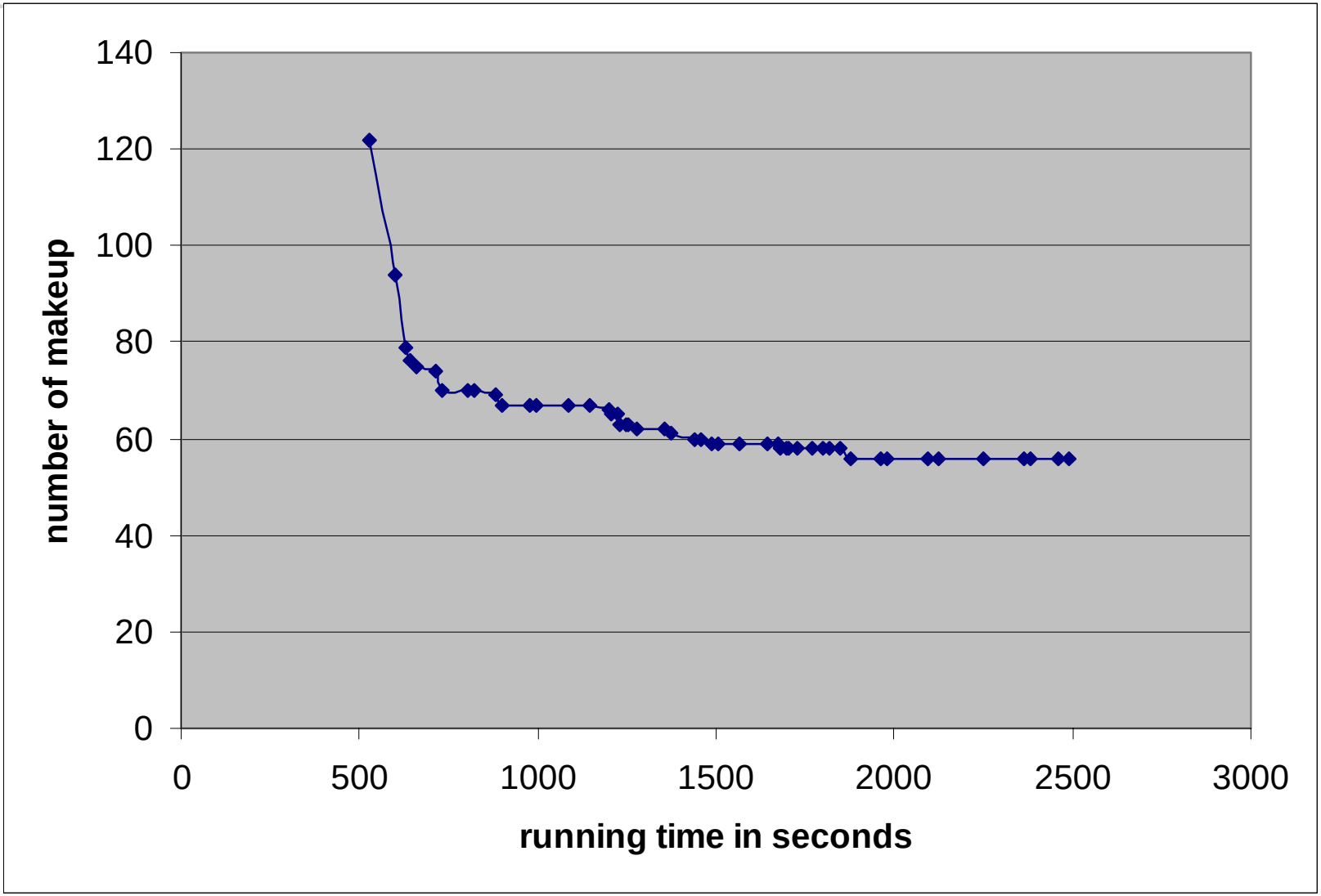
- TEE last application of legacy system
  - Mainframe, Cobol, ~1980
  - Maintenance + on-site personnel: $500,000/year
- By March 2001: decision for renewal
- TEE Schedule for AY2001/2 (End of May 2001)
  - Chuck + Legacy system
    - Partial schedule, approx. 90 makeups (4 Weeks)
  - Chuck + GAMS TEE scheduler
    - Complete schedule, no conflicts, 60 makeups (10 minutes)
    - The improver module produced schedule with 40 makeups

More Computational Results

- Three data sets 01/2,02/1(early),02/1
- Constraint violations ‘OK’

Year	Courses	Periods	Requests	Makeups
01/2	226	12	18937	38
02/1 early	213	12	18512	49
02/1	252	11	21175	61

Improvement over Time




The End