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SHARE SESSION REPORT

61	A111	LP Solution Analysis with PERUSE	10
SHARE NO.	SESSION NO.	SESSION TITLE	ATTENDANCE
Math Programming		T. R. White	SO
PROJECT		SESSION CHAIRMAN	INST. CODE
Shell Oil Co., P.O. Box 2463, Houston, TX (713) 241-3482			
SESSION CHAIRMAN'S COMPANY, ADDRESS, AND PHONE NUMBER			

Phyllis Gilmore of US Dept. of Energy described the PERUSE/XMP System for interactive analysis of LP models and solution. Description of the system is attached.

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THE PERUSE/XMP SYSTEM FOR INTERACTIVE LP MODEL ANALYSIS

By

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Presented at

SHARE Annual Meeting
New York, New York
August 22, 1983

SECTION 1

INTRODUCTION TO PERUSE/XMP

1.1. Description of the Software

This section describes the purpose and background of PERUSE. Although the speed of today's computers and mathematical programming software (MPS III, MPSX/370) is very fast and leads to model run times of a few minutes or less, the total turnaround time to validate and verify a model run is a long and tedious process that can take several hours or more. The original purpose of the PERUSE system was to facilitate interactive analysis of the solution and matrix information to reduce model turnaround time. The commands allow the user to delimit information displayed, avoid information overload and eliminate manually paging through several inches of computer printouts*. Simple reports can also be generated. With the addition of an optimization capability callable from PERUSE, the analyst can now change the model, solve it quickly, and generate answers to "what-if?" questions.

*This method of manual paging is known as PCIMPAM (Paper Clip Indexing Manual Paging Access Method), a name applied by the original PERUSE development group.

1.2 Design Concept and Description

Beginning in 1977, a group of analysts in the Energy Information Administration (EIA) developed an interactive query system called PERUSE for accessing matrix and solution values from a linear programming model. This group, which included Dr. Harvey J. Creenberg, Dr. Richard P. O'Neill, Mr. William G. Kurator, and others, laid the foundation for the development of computer-assisted analysis (CAA) programs for mathematical programming models. PERUSE is used within the Department of Energy as well as in many private sector and academic installations.

In 1982, an optimization capability was added to PERUSE. This new feature allows the analyst to make changes to the data in his model and solve the revised problem -- <u>interactively</u>! This capability results in a reduction in time necessary to make modest sensitivity changes to a model and receive the new answers. The optimizer used by the PERUSE SOLVE command is based on the XMP library of FORTRAN subroutines developed by Dr. Roy E. Marsten of the University of Arizona under several National Science Foundation grants. The optimizer is known as XMP for Experimental Mathematical Programming System.

The design purpose of XMP is to facilitate algorithmic research and model development. This system was selected because of its flexibility and ease of modification. XMP has been designed to solve LP models on the order of 1500 constraints and is not intended to compete with MPSX/370 or

MPS III which can handle problems of 8000 constraints or more.

The XMP subroutines included in PERUSE are restricted to the <u>solution</u> of mathematical programming models. There are no routines for model generation or report generation based on solutions. These tasks are best handled by other existing languages and systems such as OMNI, DATAFORM, or GAMMA. The user simply issues the command SOLVE while in PERUSE to invoke the optimization process of XMP.

SECTION 2

SAMPLE PROBLEM DESCRIPTION

2.1 Oil Production, Refinery, and Distribution (OPRD)

The following sample problem has been developed to demonstrate the use of interactive optimization using PERUSE and XMP. The model will be modified and re-optimized during an interactive session.

The problem considers the production and transportation of two types of crude oil (TG and OK) from two producing regions (Gulf Coast-08 and Mid-Continent-09) to two refining regions. Each refinery produces three products -- gasoline, distillate and residual fuel oil -- which are transported to demand regions 1, 2, and 5. Each refinery region may supply each of the three demand regions with any of the three products. The matrix structure and data for the problem are described in the following sections. The names for the objective function and right-hand side for this example (AMINCST and ZRHS) were chosen to insure their alphanumeric sort location in the PICTURE command. That is, given the other row names in the problem, AMINCST will be listed first. Given the column names in the problem, ZRHS will be listed last.

2.2 Row and Column Name Structure

A meaningful name structure is essential for good design practice when building LP models. The name structure used in the sample problem is shown below. A count of the rows and columns in each group is included in parentheses.

ROWS (Total 24)

AMINCST (1)	Objective function to be minimized
M(LO)(MT)XX1(12)	Material balance at location (LO) for material (MT) in time period 1. The XX is used as a filler and has no mnemonic significance.
MO8TGXX1 MO9OKXX1 MR1TGXX1 MR1OKXX1 MR1GAXX1 MR1DSXX1 MR1RSXX1 MR2TGXX1 MR2OKXX1 MR2GAXX1 MR2DSXX1 MR2RSXX1	
L(LO)(MD)XX1(2)	Limit of capacity in location (LO) for process (MD) in time period 1.
LR1CDXX1 LR2CDXX1	
D(LO)(PP)XX1(9)	Demand at location (LO) for product (PP) in time period 1.
DD1GAXX1 DD1DSXX1 DD1RSXX1 DD2GAXX1 DD2DSXX1 DD2RSXX1 DD5GAXX1 DD5DSXX1 DD5RSXX1	

<u>COLUMNS</u> (Total 30)

P(LO)(MT)(II)1(4)	Production of material (MT) at location (LO)
POK09111 POK09511	and supply step increment II in time period 1.
PTG08111 PTG08511	

R(LO)(MD)XX1(4)	Operation of a facility at location (LO) and
RR1OKXX1) RR1TGXX1	mode (MD) in time period 1.
RR2OKXX1 RR2TGXX1	

T(MT)(OR)(RR)1(4)	Pipeline transport of material (MT) from
TOK09R11 TOK09R21	source (OR) to destination (RR) in period 1.
TTG08R11 TTG08R21	

U(PP)(RR)(DD)1(18)	Transport by barge/tanker of material (PP)
UDSR1D11 UDSR1D21 UDSR1D51 UDSR2D11 UDSR2D21 UDSR2D51	from source (RR) to destination (DD) in time period 1.
UGAR1D11 UGAR1D21 UGAR1D51 UGAR2D11 UGAR2D21 UGAR2D51	
URSR1D11 URSR1D21 URSR1D51 URSR2D11 URSR2D21 URSR2D51	

*Items in () represent variable characters.

2.3 Dictionary Classes

The classes of variable names described in the previous section can be defined for this problem through the use of dictionary classes. The classes serve to define the mnemonic names and contain full text descriptions that will be used when producing custom reports.

<u>Locations (LO)</u>

Class OR		Oil Producing Regions
	08	Gulf of Mexico
	09	Mid-Continent
Class RR		Refining Regions
	R1	PAD 1A No. East
	R2	PAD 2A Midwest
Class DD		Demand Regions
	D1	New England
	D2	N.Y., N.J. - Mid-Atlantic
	D5	Midwest

<u>Materials (MT)</u>

Class CR		Crude Oils
	TG	Texas Gulf Coast
	OK	Oklahoma Mix
Class PP		Petroleum Products
	GA	Gasoline
	DS	Distillate Oils
	RS	Residual Fuel Oil

Operating Modes (MD)

Class MD		Operating Modes
	CD	Crude Distillation

Supply Segments (II)

Class II		Oil Supply Segments
	11	Old Primary
	51	New Primary

Transportation Modes (T)

Class T		Transportation Modes
	T	Pipeline Crude Oil
	U	Tanker/Barge Products

2.4 Data Tables

Data tables are required which describe the available crude oil supplies and capacities, the supply costs, oil transportation costs, refinery operation yields and costs, product transportation costs, and market demands. For our sample problem the data has been organized into the following tables. The table names are designed with the same care used in row and column names.

TABLE OL185

OIL PRODUCTION LEVEL AND COST

	Production Level (MB/D)*	Supply Cost Price/B
Oil Region 8	0-1,100	$5.00
	1,100 - 2,300	5.50
Oil Region 9	0-1,300	$5.25
	1,300 - 2,700	5.50

*MB/D - thousand barrels/day

TABLE TROPLPRC

OIL TRANSPORT COSTS TO REFINERY CENTERS
(Dollars/Barrel)

	Refinery Center R1	Refinery Center R2
Oil Region 8	4.00	3.00
Oil Region 9	3.50	2.00

Refineries differ in terms of their yields for each product (yield patterns). This table contains the yield patterns for refineries 1 and 2 for refined products and the associated costs.

TABLE RN185

REFINERY YIELDS AND COSTS

	Refinery R1		Refinery R2	
Crude (Mode)	TG	OK	TG	OK
Gasoline	.50	.48	.60	.50
Distillate	.25	.25	.20	.25
Residual F.O.	.15	.15	.05	.05
Cost/Barrel	.75	.75	.50	.50

The processing capacity at each refinery is given in the following table.

TABLE RNCAP

REFINERY CAPACITY

	MB/D
Refinery R1	2200
Refinery R2	2500

After the oil is refined, the oil products are shipped from the refineries to the demand regions. The transportation costs are given in the following table:

TABLE LPRC(PP)

OIL TRANSPORT COSTS TO DEMAND REGIONS
(Dollars/Barrel)

	------------Gasoline*------------		
	Demand Region 1	Demand Region 2	Demand Region 5
Refinery R1	1.64	1.63	1.73
Refinery R2	1.58	1.61	1.61

*Similar, but slightly different costs are present for distillate and residual.

The market demands are shown in the following table.

TABLE PRDEM(PP)

MARKET DEMANDS

GASOLINE	Region D1	Region D2	Region D5
Demand, MB/D	1400	600	400
DISTILLATE			
Demand, MB/D	400	300	350
RESIDUAL FUEL OIL			
Demand, MB/D	150	150	100

SECTION 3

SAMPLE PROBLEM RESULTS

3.1 Changes Made to Base Case

A summary of changes made to the base case model is listed below. Case AF is the base case and Case BF will be the new case. The crude refining capacity was increased by 800 MB/D at location R1 and reduced by 100 MB/D at location R2. The demand for distillate (DS) in region D2 was increased by 200 MB/D. The oil production limits were altered by decreasing the new primary production (51) for crude TG in oil region 08 by 300 MB/D. The crude production limits for OK crude in oil region 09 were increased for old primary (11) by 700 MB/D and for new primary (51) by 600 MB/D.

* CHANGES FROM CASEAF ARE :	NAME	CASEAF OLD	CASEBF NEW
* ZRHS	LR1CDXX1	2200	3000
*	LR2CDXX1	2500	2400
*	DD2DSXX1	300	500
* BOUND CHANGES			
* BOUNDROW	PTG08511	1200	900
*	POK09511	1400	2000
*	POK09111	1300	2000
*			
*			

3.2 Review Base Case Solution

The next command we issue is to DISPLAY the row and column answers of the original case before we change and solve the revised case. We first request a DISPLAY (D) of row answers (R) for all rows (*) which includes solution values, slack, lower and upper limit and dual activity.

The objective function value for the base case is 46510 (Row AMINCST). The dual activity for distillate (DS) in region 2 (D2) is 14.408$/Bbl. which indicates the cost increase if demand is increased for this product in this region.

```
* DISPLAY ROW ANSWERS FOR THE BASE PROBLEM
ENTER A COMMAND
NOP
D R *
```

NAME	STATUS	ACT LEVL	SLACK	LLIMIT	ULIMIT	DUAL ACT
AMINCST	BS	46510.	-.10000E+31	-.10000E+31	.10000E+31	.0
DD1DSXX1	LL	400.00	.0	400.00	.10000E+31	14.428
DD1GAXX1	LL	1400.0	.0	1400.0	.10000E+31	15.945
DD1RSXX1	BS	155.67	-5.6666	150.00	.10000E+31	.0
DD2DSXX1	LL	300.00	.0	300.00	.10000E+31	14.408
DD2GAXX1	LL	600.00	.0	600.00	.10000E+31	15.935
DD2RSXX1	LL	150.00	.0	150.00	.10000E+31	.30000E-01
DD5DSXX1	LL	350.00	.0	350.00	.10000E+31	14.388
DD5GAXX1	LL	400.00	.0	400.00	.10000E+31	15.975
DD5RSXX1	BS	125.00	-124.00	1.0000	.10000E+31	.0
LR1CDXX1	BS	2037.8	162.22	-.10000E+31	2200.0	.0
LR2CDXX1	UL	2500.0	.0	-.10000E+31	2500.0	-2.1781
MO8TGXX1	UL	.0	.0	.0	.0	5.5000
MO9OKXX1	UL	.0	.0	.0	.0	5.7139
MR1DSXX1	UL	.0	.0	.0	.0	12.978
MR1GAXX1	UL	.0	.0	.0	.0	14.305
MR1OKXX1	UL	.0	.0	.0	.0	9.2139
MR1RSXX1	UL	.0	.0	.0	.0	-.98000
MR1TGXX1	UL	.0	.0	.0	.0	9.5000
MR2DSXX1	UL	.0	.0	.0	.0	13.008
MR2GAXX1	UL	.0	.0	.0	.0	14.365
MR2OKXX1	UL	.0	.0	.0	.0	7.7139
MR2RSXX1	UL	.0	.0	.0	.0	-.85000
MR2TGXX1	UL	.0	.0	.0	.0	8.5000

```
24. ACTIVITIES WITH MASK ******** SATISFY THE CONDITION
    THE SUM OF THEIR ACT. LEVELS IS   54929.
```


The column answers are displayed for all columns with their activity levels (X), objective function coefficients (C) lower and upper limits and reduced costs (D).

```
* DISPLAY THE COLUMN ANSWERS FOR THE BASE PROBLEM
*
D C *
```

NAME	STATUS	ACT LEVL	COST	LLIMIT	ULIMIT	RED COST
POK09111	UL	1300.0	5.2500	.0	1300.0	-.46390
POK09511	UL	1400.0	5.5000	.0	1400.0	-.21390
PTG08111	UL	1100.0	5.0000	.0	1100.0	-.50000
PTG08511	BS	737.78	5.5000	.0	1200.0	.0
RR1OKXX1	BS	1888.9	.75000	.0	.10000E+31	.0
RR1TGXX1	BS	148.89	.75000	.0	.10000E+31	.0
RR2OKXX1	BS	811.11	.50000	.0	.10000E+31	.0
RR2TGXX1	BS	1688.9	.50000	100.00	.10000E+31	.0
TOK09R11	BS	1888.9	3.5000	.0	.10000E+31	.0
TOK09R21	BS	811.11	2.0000	.0	.10000E+31	.0
TTG08R11	BS	148.89	4.0000	.0	.10000E+31	.0
TTG08R21	BS	1688.9	3.0000	.0	.10000E+31	.0
UDSR1D11	BS	400.00	1.4500	.0	.10000E+31	.0
UDSR1D21	LL	.0	1.4400	.0	.10000E+31	.10000E-01
UDSR1D51	BS	109.44	1.4100	.0	.10000E+31	.0
UDSR2D11	LL	.0	1.5000	.0	.10000E+31	.80000E-01
UDSR2D21	BS	300.00	1.4000	.0	.10000E+31	.0
UDSR2D51	BS	240.56	1.3800	.0	.10000E+31	.0
UGAR1D11	BS	381.11	1.6400	.0	.10000E+31	.0
UGAR1D21	BS	600.00	1.6300	.0	.10000E+31	.0
UGAR1D51	LL	.0	1.7300	.0	.10000E+31	.59999E-01
UGAR2D11	BS	1018.9	1.5800	.0	.10000E+31	.0
UGAR2D21	LL	.0	1.6100	.0	.10000E+31	.40000E-01
UGAR2D51	BS	400.00	1.6100	.0	.10000E+31	.0
URSR1D11	BS	155.67	.98000	.0	.10000E+31	.0
URSR1D21	BS	150.00	1.0100	.0	.10000E+31	.0
URSR1D51	LL	.0	1.1100	.0	.10000E+31	.13000
URSR2D11	LL	.0	1.1900	.0	.10000E+31	.34000
URSR2D21	LL	.0	1.0900	.0	.10000E+31	.21000
URSR2D51	BS	125.00	.85000	.0	.10000E+31	.0

```
30. ACTIVITIES WITH MASK ******** SATISFY THE CONDITION
    THE SUM OF THEIR ACT. LEVELS IS   17494.
```

3.3 Interactively Revise the Model

The changes described in Section 3.1 are made with the CHANGE command of PERUSE. The user enters CHANGE ZRHS,LR1CDXX1 3000 and the system responds with:

Value 2200.0 for ZRHS,LR1CDXX1 is now 3000.00.

The commands and responses are listed below:

```
CHANGE  ZRHS,LR1CCXX1  3000.
 VALUE    2200.0       FOR ZRHS       ,LR1CDXX1  IS NCW   3000.00
CHANGE  ZRHS,LR2CDXX1  2400.
 VALUE    2500.0       FCR ZRHS       ,LR2CDXX1  IS NCW   2400.00
CHANGE ZRHS,DD2DSXX1 500.
 VALUE    300.00       FCR ZRHS       ,DD2DSXX1  IS NCW    500.00
CHANGE PTGO8511,BOUNDUP 900.
 VALUE    1200.0       FOR PTGO8511,BOUNDUP   IS NOW    900.00
CHANGE POKO9511,BOUNDUP 2000.
 VALUE    1400.0       FOR POKO9511,BCUNDUP   IS NCW   2000.00
CHANGE POKO9111,BCUNDUP 2000.
 VALUE    1300.0       FOR POKO9111,BCUNDUP   IS NCW   2000.00
```


We now look at selected matrix coefficients to verify the changes using the LIST command. The first LIST (L) checks columns that begin with P (Production) and their bound values (BO). The next two LIST commands check the right-hand-side (ZRHS) and the coefficients for capacity rows (LR1,LR2) and demand in region D2 for distillate (DD2D*).

```
* LOOK AT REVISED MODEL
L P*,BO*
  POKO9111      BCUNDUP       2000.0
  POKO9511      BOUNDUP       2000.0
  PTGO8111      BOUNDUP       1100.0
  PTGO8511      BOUNDUP       900.00
       4   COEFFICIENT(S) SATISFY THE MASK


L Z*,L*
  ZRHS          LR1CDXX1      3000.0
  ZRHS          LR2CDXX1      2400.0
       2   COEFFICIENT(S) SATISFY THE MASK


L Z*,DD2D*
  ZRHS          DD2DSXX1      500.00
       1   COEFFICIENT(S) SATISFY THE MASK
```

3.4 OPTIMIZE with XMP

The next command issued is SOLVE, which solves the revised model. The total cost has increased from 46510 to 50567. The row answers show that the marginal cost (dual activity) for DS in region 2 (D2) has jumped from 14.408 to 44.278$/Bbl. The increased demand has sharply increased the cost of producing distillate.

```
*         CALL SOLVE
SOLVE
     BEGIN SOLVE FOR CURRENT PACKED MATRIX
XFEAS...FEASIBLE SOLUTION FOUND.
PHASE 2... OPTIMAL SOLUTION FOUND.
    OBJ VALUE =   50567.
      SOLVE HAS ENDED
*             SOLUTION AFTER SOLVE
*      SELECTED ROW VALUES
D R L* X,D
  NAME STATUS  ACT LEVL DUAL ACT
LR1CDXX1 BS   2620.0       .0
LR2CDXX1 UL   2400.0     -1.8594

    2. ACTIVITIES WITH MASK L******* SATISFY THE CONDITION
       THE SUM OF THEIR ACT. LEVELS IS   5020.0

D R DD2* X,D
  NAME STATUS  ACT LEVL DUAL ACT
DD2DSXX1 LL   500.00      44.278
DD2GAXX1 BS   686.00      .0
DD2RSXX1 LL   150.00      .30000E-01

    3. ACTIVITIES WITH MASK DD2***** SATISFY THE CONDITION
       THE SUM OF THEIR ACT. LEVELS IS   1336.0
```


The production column values only are displayed below and indicate the major change is to reduce the production of high cost TG crude (PTGO85111) from 737 to 0 MB/D. The last command, END, terminates the PERUSE session.

```
*      LOOK AT PRODUCTION COLUMN VALUES
D C P* X,C,U,D
  NAME STATUS  ACT LEVL    COST        ULIMIT      RED COST
POKO9111 UL   2000.0      5.2500       2000.0      -.28260
POKO9511 UL   2000.0      5.5000       2000.0      -.32600E-01
PTGO8111 BS   1020.0      5.0000       1100.0       .0
PTGO8511 LL    .0         5.5000       900.00       .50000

    4. ACTIVITIES WITH MASK P******* SATISFY THE CONDITION
       THE SUM OF THEIR ACT. LEVELS IS   5020.0

END
END COMMAND ENCOUNTERED. PERUSE TERMINATES
```

3.5 Command Input File Listing

The previous output was generated using the input file feature of PERUSE. The user prepares a file of commands as shown below and supplies the file name to PERUSE. This feature saves analyst time when repetitive commands are required.

```
*
* CASEBF INPUT FILE PERUSLIB(PERINB)
NOP
* CHANGES FROM CASEAF ARE :    NAME      CASEAF      CASEBF
*                                         OLD          NEW
* ZRHS                         LR1CDXX1   2200        3000
*                              LR2CDXX1   2500        2400
*                              DD2DSXX1    300         500
* BOUND CHANGES
* BOUNDROW                     PTG08511   1200         900
*                              POK09511   1400        2000
*                              POK09111   1300        2000
*
* CHECK SOME KEY VALUES IN ORIGINAL MODEL
*  MATRIX VALUES
L ZR*,L*
L Z*,DD2D*
L P*,BO*
* LOOK AT SOLUTION BEFORE SOLVE. NOTE ACT. LEVEL, DUALS
*  THEY WILL MATCH CASEAF (ORIGINAL)
*  CAPACITY AND DEMAND IN  REGION D2 ROW ANSWERS
D R L* X,D
D R DD2* X,D
*       LOOK AT PRODUCTION COLUMN VALUES
D C P* X,C,U,D
*
*        CHANGE AND REVISE MODEL
CHANGE ZRHS,LR1CDXX1 3000.
CHANGE ZRHS,LR2CDXX1 2400.
*     CHANGE DEMAND
CHANGE ZRHS,DD2DSXX1 500.
*    CHANGE UPPER BOUNDS ON PRODUCTION
CHANGE PTG08511,BOUNDUP 900.
CHANGE POK09511,BOUNDUP 2000.
CHANGE POK09111,BOUNDUP 2000.
*
* LOOK AT REVISED MODEL
L Z*,L*
L Z*,DD2D*
L P*,BO*
*          CALL SOLVE
SOLVE
*               SOLUTION AFTER SOLVE
*       SELECTED ROW VALUES
D R L* X,D
D R DD2* X,D
*       LOOK AT PRODUCTION COLUMN VALUES
D C P* X,C,U,D
END
```


3.6 PERUSE/XMP Saves Time

A major advantage to the use of PERUSE/XMP is the time the analyst can save when making minor corrections to a model. By minor corrections, we mean that a few values are changed to either correct an error or resolve an infeasibility. Major changes, which involve many values or changes to the permanent model data, should be done with existing model generation software to keep the model current. The following table compares the elapsed time required to make the changes previously described when the MPS REVISE procedure is used.

Minor Model Revisions with PERUSE

Approach:	MPS REVISE	PERUSE
Optimizer:	WHIZARD	XMP
Time:	HH:MM:SS	HH:MM:SS
1. Problem Identified	00:00:00	00:00:00
2. Revisions Made		
Revise Input	00:11:14	
Change Command		00:02:25
3. Re-Optimize Run		
New Solution	00:02:00	00:00:10
4. Solution Reviewed		
TSO "Output"	00:08:00	
PERUSE Display		00:01:00
TOTAL ELAPSED TIME	00:21:14	00:03:35

3.7 XMP Optimization Time

Although XMP was not designed to compete with MPSX/370 or MPS III, the speed of optimization for typical models of se veral hundred rows is very satisfactory. We believe that the most important timing consideration is the time required for the analyst to obtain answers to the current model run. Optimization time is only one part of the several steps required to produce answers from model runs. The next page displays results of solving a 250 and 500 row model from scratch using WHIZARD of MPS III and XMP. The models are 10 and 20 time period versions, with inventory transfer, of the sample problem described in this paper.

PERUSE/XMP

TIMING RESULTS

IBM 3033

MODEL:	10 periods		20 periods	
ROWS:	254		504	
COLUMNS:	475		955	
ELEMENTS:	1802		3622	
UNIQUE ELEMENTS	581		1119	
	WHIZARD	XMP	WHIZARD	XMP
STARTING BASIS	NO	NO	NO	NO
OPTIMIZATION TIME				
CPU SECONDS	3.4	N/A	8.3	N/A
ELAPSED TIME, MM:SS	00:53	01:00	01:57	04:45
ELAPSED TIME DIFFERENCE	7 seconds		2 min 48 sec	
%	BASE	+13	BASE	+143

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SESSION REPORT

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61	A216	Considerations in Designing a GML Application	75

PROJECT	SESSION CHAIRMAN	INST. CODE
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Session Number A216