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RESEARCH PROJECT INITIATION

Date: July 11, 1974

Project Title: Instructional Scientific Equipment

Project No: G-41-506

Principal Investigator Dr. Donald C. O'Shea

Sponsor: National Science Foundation

Agreement Period: From June 15, 1974 Until June 30, 1976

Type Agreement: Grant No. GZ-3061

Amount: $10,600 NSF (G-41-506)
10,600 GIT (G-41-218)
$21,200 TOTAL

Reports Required: Final Report
Fiscal Report

Sponsor Contact Person (s):

Instructional Scientific Equipment Program
National Science Foundation
Washington, D. C. 20550

Wilbur W Bolton Jr
grant officer
NSF Wash 20550

Assigned to: Physics

send letter

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RA-3 (6-71)

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Posted 8/ aod8 OH

Date: July 15, 1976

B3770 NF

Project Title: Instructional Scientific Equipment Program

No Action required

Project No: G-41-506

Project Director: Dr. Donald C. O'Shea

Sponsor: National Science Foundation

Effective Termination Date: 6/30/76

Clearance of Accounting Charges: 6/30/76

Grant/Contract Closeout Actions Remaining: NONE

- _ Final Invoice and Closing Documents
- _ Final Fiscal Report
- _ Final Report of Inventions
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other ____________________

Assigned to: Physics (School/Laboratory)

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CA–4 (3/76)

G-41-506

Instructional Scientific Equipment Program

Project Director's Final Report

Grant number: 7415183
(formerly GZ-3061)

Discipline: Physics-Optics

Date: May 30, 1976

To: Division of Higher Education in Science
National Science Foundation

From: Dr. Donald C. O'Shea — DCO'S
Project Director

Georgia Institute of Technology, Atlanta, Georgia 30332

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Short Summary of the Program

The NSF Instructional Grant has enabled the School of Physics to round out a course of instruction in applied optics. With the assistance of NSF funds and federal excess property, laboratories in thin film deposition, grinding and polishing, and optical testing have been established. About twenty students have participated in the program thus far. A revised syllabus is being prepared for submission to the Institute's Undergraduate Curriculum Committee for formal approval. The facilities established under this grant, have also been used in the Master's level applied optics program.

I. Project Director's Covering Letter

A. Instructional Improvement

1. Establishment of courses. All of the courses proposed in the original description of the project have been given once during the two year duration of the grant. Eight students completed the thin film deposition laboratory; one student completed the ginding and polishing lab and during the reporting quarter ten students are completing an optical design course with an optical design laboratory.

2. Specific Courses and Accomplishments

   (a) Thin film laboratory. The course was given during the winter quarter of 1975 and had an enrollment of eight students, all of whom completed the course. The textbook was Chapters 20 and 21 of Military Handbook 141-Optical Design. The course consisted of one hour of lecture per week and three hours of laboratory. The lectures consisted of the derivation of Maxwell's equations at a dielectric interface and their applications to construction of specialized thin film structures.

   The laboratory consisted of a series of progressively more difficult problems in deposition. Table I lists the contents of each laboratory during the 9 weeks. The final two weeks consisted of a design project by each of the students. All students starting with no

TABLE I - THIN DEPOSITION LAB EXPERIMENTS

Week	EXPERIMENT
1	Deposition Vacuum System - Familiarization with vacuum system and pumpdown to below 10^{-5} μ Hg.
2	Depositing a Metal Film - Ultrasonic Cleaning procedures, high current transformer taps, metal film deposition.
3.	Optical Monitoring System - Introduction to lock-in techniques, optical adjustment of test-pieces - mock - up on outside of bell jar.
4.	Depositing a Dielectric Film - Deposition of a single quarter wave layer of $Mg F_2$ on glass using the optical monitoring system
5.	Depositing a "V" coat - Deposition of a double layer of MgF_2 and SiO on glass using the optical monitoring system
6	Depositing a "W" coat - similar to "V" coat (will be dropped in future labs)
7	Depositing a Reflector - deposition of alternating quarter wave layers of MgF_2 and ZnS to 5 layers run transmission curve on result.
8 & 9	Design Problem - Design multilayer thin film, calculate its transmission curve and deposit the film.

previous knowledge of thin film deposition were able to understand and operate all of the equipment used in the deposition process, to deposit three different types of anti-reflection coatings and a high reflectivity mirror. Some of the special problems misfired, usually because the student was too ambitious in his design. Several students produced creditable products and one deposited a Fabry-Perot type interference filter with a 18nm bandwidth (See Fig. 1), a considerable accomplishment for a beginning student.

The NSF Equipment Grant provided instrumentation needed to monitor the progress of the thin-film deposition process. Through the use of this equipment the thin film deposition system, was used at its full capability for the first time. Besides providing control over the deposition process, the monitoring system introduced students to the use of phase sensitive electronic techniques.

(b) Fabrication Laboratory. Starting with a core drilling process through which lens blanks are generated by cutting circular discs from a slab of glass, the student enrolled in the laboratory, ground a series of blanks to a fine surface and then proceeded to bring these blanks to an excellent polish. Further polishing was done to bring the surface to a truly flat surface, as determined by interferometric measurements.

The equipment, including the two spindle Strasbaugh polishers, is housed in a newly renovated room with partitioned areas to separate grinding and polishing operations, (Figure 2). The thin film deposition

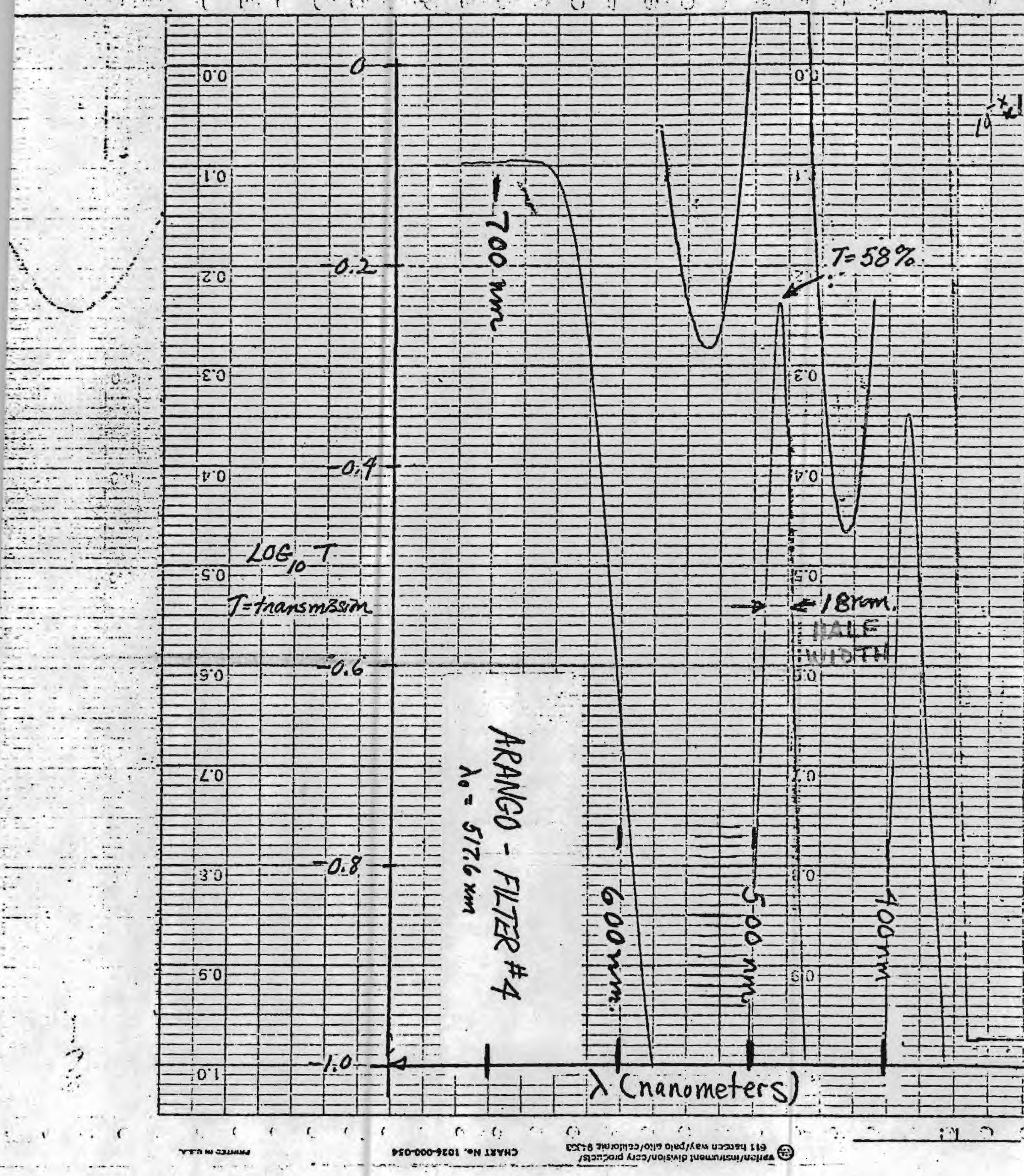

Figure 1. Transmission curve of narrowband filter. Filter made by student in thin film deposition laboratory.

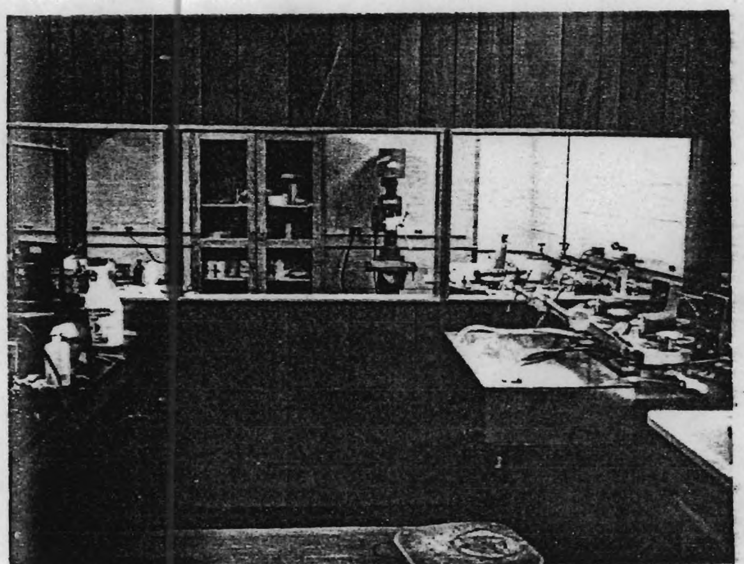

Figure 2. Polishing (near camera) and grinding bays of fabrication laboratory.

station will also be moved into the room very shortly.

(c) Optical Testing Laboratory. In conjunction with a three hour lecture portion on Optical Design (Text: Modern Optical Engineering by Warren J. Smith, published by McGraw-Hill (1966)), a three hour laboratory on optical testing is given. In this laboratory, students working in two member teams, measure the aberrations and the resolution of a single plano-convex lens during one week, then perform the same experiment on a well corrected compound lens the next week. Table II lists the experiments.

The optical testing laboratory was set up with NSF Equipment Funds. The modulation transfer function analyzer is the most modern method one has of evaluating optical systems. The contrast between this method and the time honored bar chart method of testing is quite dramatic. Figure 3 shows both systems set up in laboratory. Two devices were devised for the aberration section of the laboratory and their design will be the basis of a paper to one of the optical journals.

3. Future of the program.

Now that all of the proposed courses and laboratories have been given at least once a formal proposal for the curriculum approval will be made. The Optical Design course plus laboratory will be proposed as a four credit course (three hours lecture plus three hours of laboratory) with no changes from the present special problem course. The Optical Fabrication Laboratory will be changed drastically, however. It is not efficient to teach both a grinding and polishing course and a thin film deposition course, so the two will be combined into a single course.

TABLE II - OPTICAL TESTING LABORATORY EXPERIMENTS

Experiment	Week	Description	Lens
A1	1	Lens aberration - Hartman test	Single
A2	2	" " - " "	Compound
B1	1	Lens aberrations - Star test & Foco-collimator	Single
B2	2	" " - " "	Compound
C1	1	Resolution Chart Test	Single
C2	2	" " "	Compound
D1	1	Modulation Transfer Function Analyzer	Single
D2	2	" " " "	Compound

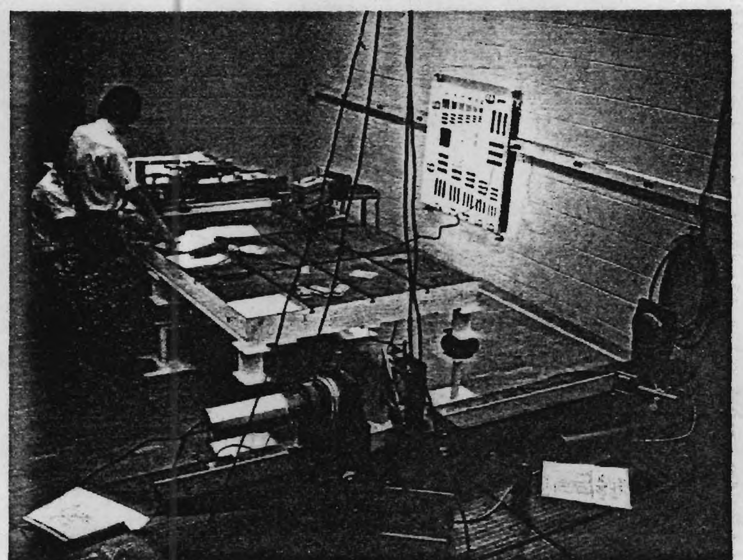

Figure 3. Modulation transfer function analyzer (foreground) and resolution chart experiments in the optical testing laboratory.

With the addition of these two laboratory based courses, plus a seminar in contemporary optics and a course in scientific photography, the applied optics program now has an impressive curriculum for an undergraduate study (Table III). A number of undergraduate students are now enrolled in the applied optics track. Their progress and their reaction to the program will be used to modify the program after two years.

B. Other impacts of grant

A few of the students taking the laboratory-based courses initiated under this grant were graduate students. The applied optics track at the Master's degree level has also benefited in that the fabrication and testing facilities are also available for formal course work and special problems for graduate students. This has enhanced the graduate student program since it leans rather heavily on the theoretical side of applied optics.

C. Project difficulties

The only difficulty encountered during the progress of this grant was that of inflation. Price rises between the time the the project was proposed and the time it was funded were staggering. To give but one example: Item 13 of our original budget consisted of a series of 7 items costing $6,175. When the items were ordered they would have totalled in the neighborhood of $8,500. One Item had to be dropped and replaced by a borrowed piece of equipment

TABLE III - APPLIED OPTICS COURSES IN THE SCHOOL OF PHYSICS

	Course Number	Title	Lecture Hours	Lab Hours	Academic Credits
	Physics 3223	Geometrical Optics	3	0	3
	" 3224	Optical Instruments Laboratory	1	3	2
	" 3225	Fourier Optics	3	0	3
	" 3226	Advanced Optical Physics Lab	1	3	2
	" 3229	Vacuum Ultraviolet Lab	1	3	2
*	" 3xxx	Scientific Photography	2	3	3
	" 3571	Laser Physics	3	0	3
*	" 4xxx	Optical Fabrication Lab	2	3	3
*	" 4yyy	Optical Design	3	3	4
*	" 4zzz	Seminar in Contemporary Optics	2	0	2

* New Courses

Only through borrowing, improvising and using Federal excess property were we able to maintain our objectives for the project. The table of equipment substitution tells the story very graphically.

D. Utilization of Federal excess property.

As pointed out above, the excess property allowed us to remain within budget and to enhance certain laboratory experiments. For example, the School of Physics has acquired four additional polishing and grinding spindles in addition to the two we bought from grant monies. This will permit larger laboratory sections and will use the instructor's time more efficiently. We also obtained a drill press to make lens blanks by core drilling. This enables the student to learn one more step in the fabrication process and saves additional money since a single lens blank costs $0.50 or more, depending upon quantity. In addition, to the drill press and polishers we have collected sufficient test flats to last us for many years.

The Thin Film deposition system has also benefited from the excess property acquistions. A strip chart recorder replaced one of the items on the budget. This instrument is superior to the one we were going to buy. Also we were able to provide a better understanding of lock-in techniques and operation with an oscilloscope from Federal excess property. Finally, a number of collimators, optical levels and other optical systems were acquired for the optical testing laboratory.

II. TABLE OF EQUIPMENT SUBSTITUTIONS AND ADDITIONS

Estimated Cost	Description	Actual Cost	Description
3540	Strasbaugh 16" polishers (2 @ 1770)	5109	1 Strasbaugh 16" Double spindle polisher, pressure actuated and slurry feed added.
320	8 Strasbaugh 18V Laps	0	Not bought - made in machine shop.
800	4 Test Flats and Curve Sets	0	Federal excess property for flats; curve set still needed.
287	Cut-off Machine (Felton DH-1)	334	Unchanged.
1845	McPherson Scanning Monochromator (EV-700)	905	Oriel Scanning monochromator.
525	McPherson Visible-UV Light Module (EV-701-50)	679	Unchanged.
425	McPherson Photomultiplier Module (EV-701-30)	110 335 585	Photomultiplier housing High Voltage Power supply Laser Energy Light Chopper
370	McPherson Readout Module	695	Pacific Photometric Lockin Amplifier
420	Heath Chart-Recorder (EV-205-11)	0	Federal excess property - Texas Instruments - 2 pen recorders.
326	Denton Vacuum Adjustable Work Fixture	370	Unchanged.
325	Denton Vacuum Substrate heater	365	Unchanged.
237	Cole-Parmer Ultrasonic Cleaner Cleaners	212	Fisher Ultrasonic cleaners.
2350	Ealing Modulation Transfer Function Analyzer consisting of Basic Electronic Module	0	Not bought - use borrowed lock-in amplifier.
1825	Basic Scanner	2400	Unchanged.
825	Spacial Frequency Range Selector	1125	Unchanged.
495	Multiple Slit Unit	750	Unchanged.
295	Lamphouse	400	Unchanged.
250	Collimator	400	Unchanged.
135	Collimator spacer	80	Unchanged.

II. continued

Estimated Cost	Description	Actual Cost	Description
0	Viewing Unit	800	Added for ease of alignment.
170	Photomultiplier tube Hammatsu R268	85	Photomultiplier tube EM1 9856KB.
250	Hewlett-Packard High voltage supply	302	Unchanged.
495	Ealing Utility Lathe Bed Bench	615	Unchanged.
525	Ealing Horizontal Translation Units (3 @ 175)	636	Unchanged. (2 @ 318)
530	2 Ealing Vertical Translation Units	753	Unchanged.
450	Ealing Cross Slide	0	Dropped from system.
405	Ealing Angle Brackets (3@ 135)	598	Unchanged. (3 @ 199)
395	Ealing Rotary Unit	752	Unchanged. (2 @ 376)
330	3 Ealing Optical Bench Carriers	399	Unchanged.
235	Ealing spacer units (2 @ 65, 3 @ 35)	0	Dropped from system.
285	Ealing- Zeiss profile Optical Bench	369	Unchanged.
282	Ealing Pin mount Carriers	395	Unchanged.
115	Ealing Foncault Knife Edge	88	Unchanged. (obtained on sale)
195	Ealing Multiple Lens holder	220	
$20,257	ESTIMATED TOTAL COST	$20,865	ACTUAL TOTAL COST

Difference between estimated and actual costs made up through smaller purchases of some itemized expendables or purchases of expendables from other funds.