Cost Variance Analysis

This document provides a cost variance analysis of the LAT Rebaseline proposal. The budget history since the May 2002 baseline time is shown in a previous section. All amounts discussed here are burdened with indirect costs and escalation. Contingency is not included in any of the discussions in this section, but is described separately in the "LAT Project Contingency Analysis" section.

It is important to note that the values given in the text below are typically rounded and approximated figures derived from (or in preparation of) formal change requests of the LAT project. Items discussed do not sum to the total variance. They are representative of the most significant changes. Values in the tables are correct.

The cost variances since between the current baseline and this rebaseline proposal are described. The baseline values at the time of the July 2003 rebaseline are referenced.

WBS 4.1 TEC

The July 2003 rebaseline cost estimate was $119,504K. Since then the baseline has increased by formal change control processes to $133,187K. The rebaseline proposal estimate for the budget at completion (end of FY05) is $150,566K.

(K$)	Rebaseline Jul-03[1]	Current Baseline Dec-04	New Estimate	Variance
Budget at Completion	$119,504	$133,187	$150,566	$17,379
Contingency	$14,345	$2,798	$5,419	$2,621
Total Estimated Cost	$133,849	$135,985	$155,985	$20,000

The increased costs are the result of the following.

- A larger number of anomalies were uncovered during engineering model (EM) testing than anticipated.
- The electronics support equipment was more extensive than planned:
  - more test sets to support the compressed manufacturing schedules of the other subsystems,
  - a higher fidelity test stand was required to verify the system integration and the flight software than was the original plan, and
  - more manufacturing support was required to get the flight electronics boxes into production.
- The project experienced more performance problems than anticipated with the vendors of the Tracker multichip modules (MCMs), the Tracker cables, the DAQ electronics boxes, and the thermal control system.

[1] Implemented in the LAT project control system, and first status reports, November 2003.

- Staff was added to support the required documentation.

The schedule for the fabrication phase is proposed to be extended to reflect planned milestone delivery to DOE at the end of September, 2005 (delayed from mid-July 2005). The Level 1 milestone for approval of CD-4 is not impacted.

WBS 4.1.1 Instrument Management

Jul. 03 Rebaseline $15,502K
Current Baseline $16,911K
Rebaseline Proposal $17,647K

The schedule was extended for this level-of-effort subsystem, to correspond with the revised DOE deliverable dates. SU-HEPL science preparation manpower was increased with the addition of two graduate students ($126K).

WBS 4.1.2 System Engineering

Jul. 03 Rebaseline $6,588K
Current Baseline $7,047K
Rebaseline Proposal $7,618K

The schedule was extended for this level-of-effort subsystem, to correspond with the revised DOE deliverable dates.

WBS 4.1.4 Tracker

Jul. 03 Rebaseline $13,595K
Current Baseline $17,126K
Rebaseline Proposal $19,927K

Labor

More manpower has been required at SLAC to support the Tracker than was planned, due to schedule delay. There is a plan to roll off that extra manpower toward the end of tower production, after all of the electronics has been delivered. Some engineering and technical support will be maintained through the end of the fiscal year to support receiving and testing of towers at SLAC and to support integration and test ($1.3M). In addition, there is $330K for manpower that will be needed in Italy through that same period.

MCM and Cable Production

Additional payments of $73K and $53K are needed to support Teledyne production, to make the improvements needed to get production restarted and to support our on-site quality assurance (QA) representative for the extended production schedule. Additional connectors and connector-savers are necessary to support yield losses of MCMs and cables and the connectors themselves ($127K). This takes into account a doubling of the unit price since the original order. More pitch adapters are required to replace parts lost from yield ($42K), and $40K is estimated to be needed to pay Teledyne for labor applied to assemblies rejected because of defective pitch adapters.

Flight Parts

Supplies of several flight parts will run low due to rejected assemblies. The remaining silicon detector stock at Hammamatsu is being purchased, with $62K being paid by the project and the rest by Japan. The project also needs about 75 more bias circuits ($15K), and $45K of carbon-carbon material for tray fabrication. An additional ASIC run is required ($40K).

In addition, $150K in costs for previously unanticipated miscellaneous parts, adhesives, and tools to support flight production has been included.

The last two towers, which will be used in the beam test, will be made to non-flight specifications, saving $200K.

Ground Support Equipment

A thermal quartz crystal microbalance is required to support tower thermal-vacuum testing ($27K). Ground support equipment (GSE) and a few flight parts such as corner brackets have been in work at SLAC ($50K). This was delayed by the safety stand-down and then had to be sent outside of SLAC for completion. Additional Ground Support Equipment is needed at SLAC to support testing of towers when they arrive ($34K). There will be $50K in expenses for EMI/EMC qualification testing of the Tracker tower.

WBS 4.1.5 Calorimeter

Jul. 03 Rebaseline $22,648K
Current Baseline $22,022K
Rebaseline Proposal $23,060K

A summary of the cost variances by Calorimeter WBS element follows.

4.1.5.1 Management

There is no increase in staffing levels. A positive cost variance covers the extension of staff to the end of the fiscal year.

4.1.5.2 System Engineering

Manpower has been added to complete assembly and test (A&T) of Calorimeter modules, through May 2005. Based on experience with the first five modules, one additional engineer is required to keep up with tests, data review and reports. The total increase is $293K.

4.1.5.3 Reliability and Quality Assurance

Manpower has been added to extend the assembly and test program. Based on experience of first five modules, one additional QA inspector is required to keep up with assembly and test of modules. This reflects the current level of activity. The total increase is $165K.

4.1.5.5 Crystal Detector Elements

$618K was recovered from an underrun in the manufacturing process at Swales.

4.1.5.6 Pre Electronics Module

There are no changes to the plan. The cost increase ($49K) is due to anomalies encountered during the startup of fabrication.

4.1.5.7 Analog Front End Electronics

The total cost increase is $613K. Of this, $417K is due to anomalies encountered during the startup of fabrication. The future program includes additional personnel and materials to assemble and test the remaining AFEE cards. This estimate is based on the costs of assembly and test of the first 40 AFEE cards and is 12 man-months of labor. This effort completes in January 2005.

4.1.5.9 CAL Assembly and Test

The cost increase of $566K includes $53K for the Engineering Model, $81K for flight module assembly to date, $26K for EGSE, $38K for software support, and $118K for facilities support.

The new work includes support for the extension of the LAT Calorimeter integration and test (I&T) at SLAC, and extending software support through the LAT integration period. The total increase in labor is 14 man months. Environmental test on modules 15 and 16 has been removed (reduction of $200K).

4.1.5.A LAT I&T

Additional labor to support I&T activities and performance analyses is offset by eliminating environmental testing of the last two modules. Changes include redistribution of labor that was scheduled to support the calibration unit beam test in summer of 2005. Additional science analysis manpower has been added to support I&T.

WBS 4.1.6 Anticoincidence Detector (ACD)

Jul. 03 Rebaseline $13,870K
Current Baseline $15,595K
Rebaseline Proposal $17,241K

In April, 2004 the ACD team performed a bottoms-up cost-to-complete estimate. The LAT configuration control board approved the FY04 budget increase, but delayed approval of the identified FY05 budget increase ($226K). Since that time, the ACD has encountered several challenging technical issues. Most notably, the breaking of photomultiplier tubes (PMTs) and hardware and software issues with the electrical ground support equipment (EGSE). These two technical issues have required additional manpower to address and resolve as well as causing the Ready for Integration (RFI) date of the ACD to be delayed to May, 2005. Nearly all of the additional budget identified in the ACD cost-to-complete exercise is in the form of manpower (some manpower is covered as materials due to the method used for procurement). A brief summary of the cost variances for each of the ACD WBS elements follows.

4.1.6.1 Management/Systems Engineering/Science Support

This element had been under running, but due to the schedule extension, there is a cost variance of $186K.

4.1.6.2 Safety and Mission Assurance

The estimated cost overrun for this element is $224K. This is all manpower and is directly attributed to a schedule delay as well as insufficient QA support identified in the

baseline plan. One QA engineer had been planned, but that level of support was insufficient due to the level of work identified.

4.1.6.3 Tile Shell Assembly

Additional manpower has been required to complete detailed design drawings and analysis. The cost of mechanical hardware was also underestimated. The total estimated cost variance is $181K.

4.1.6.4 Base Electronics Assembly

Due to the technical issues with the PMTs and EGSE, planned work on the electronics has not yet occurred, resulting in a significant overrun in manpower. There have also been material cost variances due to the testing of ASICs and the higher-than-planned cost of mechanical hardware. The total increase is $400K.

4.1.6.5 Micrometeoroid Shield/Thermal Blanket

The materials required to build up the micrometeoroid shield/thermal blanket were underestimated. Due to procurement issues, a cost increase will be realized. The total increase is $243K.

4.1.6.6 Mechanical Qualification and Calibration Unit

There is a cost variance of $52K, all manpower.

4.1.6.7 Integration and Test

The cost variance for this element is all manpower and is estimated to be $232K, the majority of which is due to the schedule delay. This will be partially offset by reducing thermal vacuum testing and EMI testing (reduction of $100K).

4.1.6.8 LAT Integration and Test

The cost variance for this element is estimated to be $70K, the majority of which is due to the schedule delay.

4.1.6.9 Ground Support Equipment

A cost increase of $152K has been identified, due to an increase in both material costs and labor required to fabricate test hardware and electrical harnesses.

WBS 4.1.7 Electronics, Data Acquisition, & Flight Software

Jul. 03 Rebaseline $18,733K
Current Baseline $22,238K
Rebaseline Proposal $28,524K

Management

An additional $289K labor and $189K M&S is requested due to schedule extension and additional tech writers (travel is decreased by $40K). Due to an unanticipated large number of required drawings, documents and procedures, all technical writers were required for a longer duration than expected. More iterations of documents, drawings and procedures were needed before release cycle was complete. Some were hired on a purchase order and thus appear as M&S. The additional labor comprises four tech writers for about five months.

Electrical Ground Support Equipment

More stations were required than originally budgeted, as well as additional rework/iterations to update stations to the latest version. The total cost increase requested is $808K in labor and $608K in M&S. Assembly was more expensive due to expediting cost to meet the delivery schedule. Labor was necessary to test the stations to meet requirements for EGSE to connect to flight hardware. Design, assembly, and fabrication of the break-out boxes was added to perform safe-to-mate procedures. Tower electronics modules and power supplies (TEM/TPS), GASU components, and assembly of the boards and harnesses were more expensive that planned.

Flight Software

An additional $406K in labor and $508K of M&S is requested (some manpower is covered as materials due to the method used for procurement). This includes a flight software manager, additional software engineers for software testing, and technical writers to support the software engineers.

Test Bed

The test bed is much more instrument-similar than originally planned, in order to reduce risk with respect to timing, triggering, event-flow at high trigger rates. More labor was needed to design, build, test, and maintain the test bed. The DAQ hardware on the test bed was changed several times to reflect revisions in design. Heater control and required equivalent loads will be added. An additional $1,088K in labor and $255K of M&S is requested.

Dataflow Electronics

An additional $204K in labor and $268K of M&S is requested.

Additional iterations were necessary on engineering module firmware, and additional labor cost, for the TEM EM ($40K).

More effort than anticipated is needed for the TEM flight unit engineering test development, including a comprehensive performance test ($46K)

The ACD EGSE cost $88K more than budgeted for engineering effort. This was due to a more complex electronics module interface and central command distribution architecture, design, and implementation, and additional iterations to incorporate changes.

An outside contractor was hired to replace the staff GASU engineer. The GASU flight board is more complex, and thus fabrication, assembly and qualification test are more expensive than anticipated. The internal harness cost is unexpectedly high. The total cost impact is $390K.

LAT Communications Board

The LAT communication board required more labor to solve CPU/PCI interaction at high data-rates ($55K). The flight production components, boards and assembly are more complex and thus cost higher than in original budget ($169K).

GASU Global Trigger

An additional $178K in labor and $533K of M&S is requested. An engineer and technician were added to help in the design, commission, and test of the GASU. A contracted engineer was hired to replace the staff engineer. Flight fabrication is costing substantially higher than budgeted. The GASU is more complex than anticipated in order to meet all trigger, dataflow, and event-builder functionality.

Spacecraft Interface Unit (SIU)

An additional $78K in labor and $507K of M&S is requested. This includes crate back-planes, storage interface board and complete crate integration, fabrication, testing. The labor cost for the SIU crate commissioning and testing is more expensive than planned. Flight production of crates is more complex. Qualification and test effort is more complex than anticipated.

Power Conditioning

Originally, the tower power supplies were to be contracted. Proposals were $4M over budget due to low-noise, high-efficiency, multi-voltage requirements in circuits and testing. The RFP was cancelled and replaced by an in-house effort which reduced the cost substantially. Nonetheless, $700K more than the original budget for design, fabrication, and testing is required ($226K labor and $473K M&S).

Cable Harness

The cost of labor is reduced by $60K due to work being transferred to vendors. An expected overrun of $174K in M&S in cable fabrication and assembly is based on vendor quotes.

Support for I&T

This effort has been redistributed to correspond with the delivery of the flight unit milestones, resulting in a reduction in this area of $139K.

WBS 4.1.8 Mechanical Systems

Jul. 03 Rebaseline $13,384K
Current Baseline $14,179K
Rebaseline Proposal $15,840K

Labor

This increase consists of $40K for the multi-layer insulation (MLI) blanket design. Very early on in the program, the ACD subsystem at GSFC was responsible for the LAT MLI design and fabrication. Because of the complexity of the MLI interfaces with the spacecraft, radiators and LAT external features, it was decided to pull this work back to SLAC. Additionally, thermal engineering support is now available at SLAC to support this task.

Materials

This increase consists of $1,581K additional budget to complete the Lockheed Martin (LM) contract. There are two main cost drivers: 1) Lockheed schedule delays and 2) SLAC-imposed changes.

1) LM overran the following tasks:

- radiator design,
- radiator analysis (structural development),
- radiator tooling design & fabrication,
- radiator thermal controls design, and
- X-LAT plate analysis.

LM has re-established the Heat Pipe Product Center in Sunnyvale, CA after it was moved to Mississippi. GLAST was the second program to go through the Center. The heat pipe fabrication effort was under-quoted, as these units were the highest complexity units built to date. The tooling necessary to produce these parts was also under-quoted. There were

heat pipe assembly weld and bending development problems that delayed the program and resulted in scrapping two flight pipes which had to be replaced. The panel fabrication has experienced delays stemming from the tight tolerances and large size of the radiators. Program-specific tools were built for the radiators and there have been problems with these, typical of any first use. The tools and/or panels had to be reworked resulting in schedule delays.

2) The following changes were made after Lockheed submitted their February 2004 cost proposal and resulted in extra costs ($200K):

- additional thermal analyses for the X-LAT plate to electronics box interface, for the thermal combs (heat shunt for the GASU box) and for the U-shaped heat pipes that were added then removed from the X-LAT plate,
- launch loads increased, requiring the Radiator interface design to be modified and the acoustic analysis to be re-done,
- MLI blanket design consultant to help SLAC with designs,
- clarification of EMI and grounding requirements added complexity to the design,
- radiator EMI coupon testing, and
- added keying features to the radiator

There is also an additional $40K for the MLI blanket fabrication, as discussed above.

WBS 4.1.9 Integration & Test (I&T))

Jul. 03 Rebaseline $6,384K
Current Baseline $8,013K
Rebaseline Proposal $9,451K

A summary of the cost variances by I&T WBS element follows.

4.1.9.1 Management

There is no increase in staffing levels, but a cost increase of $136K is requested due to the schedule extension. This cost is primarily labor.

4.1.9.4 Mechanical Ground Support Equipment

Labor costs will remain unchanged in this area. A second single-bay rotation stand and a two-bay integration stand will be built at a cost of $25K.

4.1.9.6 Integration, Facilities, Configuration & Test

There is a cost increase of $296K to maintain current staffing through the extended schedule period. An electrical technician is needed for multishift staffing during integration and system test ($65K). Additional labor will be required to meet new survey

requirements, and to provide rigging support ($37K). Clean room cleaning and consumables must be extended, as well, at a cost of $39K.

Fly-away instrumentation has been added to the environmental test at a cost of $60K. A second spacecraft-instrument interface simulator, or additional components, to provide a complete interface to test the LAT will cost $100K. This will later be used by the instrument science operations center in the test bed.

A number of additional items will be purchased, including two additional bus protection units, computing resources & servers, a Hydra-Set for supporting precision lifts, test cables for thermal vacuum and system testing, and connector savers. These items total $196K.

4.1.9.8 Environmental Test

There is a cost increase of $60K to maintain current staffing through the extended schedule period. $500K is the estimated increase in pre-environmental test support, and includes the following:

- additional NRL level of effort to support facility readiness ($70K),
- procedure development and walkthrough left out of the original estimate ($100K),
- thermal vacuum test modeling and setup design ($100K),
- thermal vacuum control system design and verification ($70K),
- thermal vacuum test harness and cabling ($75K)
- thermal vacuum cold plate fixture fabrication ($50K)

WBS 4.1.A Performance & Safety Assurance (PSA)

Jul. 03 Rebaseline $1,486K
Current Baseline $2,935K
Rebaseline Proposal $3,844K

Subsystem activities are performed on a level-of-effort basis. The PSA budget is primarily allocated to quality engineering and inspection labor to support LAT hardware and flight software development activities. Based on a reanalysis of the cost to complete, additional funding of $909K is required beyond the current baseline. Of this additional request, $54K is SLAC labor, $825K is contract labor and $30K is M&S (travel and equipment calibration).

The quality engineering function to support hardware fabrication, assembly, and integration and test activities is staffed with three quality engineers and one electronics, electrical and electromechanical (EEE) parts engineer. The quality engineering staffing roll-off plan reflects the DAQ and Tracker component and assembly delivery schedules and integration milestones.

Source inspection efforts at LAT hardware vendor facilities are performed by three individuals. The source inspection is performed on a full-time basis at critical vendors responsible for Tracker MCM and DAQ TEM, TEM/PS, PDU (power distribution unit), GASU and SIB (spacecraft interface board) assembly. In addition, source inspection is performed on staggered deliveries of Tracker flex cables and DAQ harnesses.

The quality engineering effort to support flight software development and test efforts is staffed at 0.5 FTE.

Hardware part, component, assembly, and integration inspection is performed by two quality assurance inspectors. Inspection support will be maintained through delivery of the LAT to NRL for environmental testing.

Current quality engineering and inspection staffing is budgeted through January 31, 2004. The revised cost to complete corresponds with the revised instrument delivery date and float. Extensions beyond the planned staffing profile are attributable to technical and programmatic problems associated with Tracker MCM piece parts and assembly, Tracker flex cable fabrication and DAQ schedule delays.

WBS 4.1.B Instrument Science Operations Center

Jul. 03 Rebaseline $326K
Current Baseline $328K
Rebaseline Proposal $336K

The schedule was extended for this level-of-effort subsystem, to correspond with the revised DOE deliverable dates. The rebaseline proposal includes an increase of $8K.

WBS 4.1.C Education & Public Outreach

Jul. 03 Rebaseline $2,448K
Current Baseline $2,448K
Rebaseline Proposal $2,684K

The schedule was extended for this level-of-effort subsystem, to correspond with the revised DOE deliverable dates. This subsystem is funded only by NASA. The cost increase reflects no changes in total fiscal year budgets, and is not a draw on contingency.

WBS 4.1.D Science Analysis Software

Jul. 03 Rebaseline $3,220K
Current Baseline $3,019K
Rebaseline Proposal $3,069K

The schedule was extended for this level-of-effort subsystem, to correspond with the extended LAT schedule. Positive cost variance is returned to contingency ($150K).

WBS 4.1.E Suborbital Flight Test
Jul. 03 Rebaseline $1,321K
Current Baseline $1,325K
Rebaseline Proposal $1,325K

This WBS item is complete; there is no proposed change.

LAT Cost Variance Analysis

		LAT Project Baseline					Rebaseline Proposal				
		Baseline	CDR/CD-3	Rebaseline		Current	New	Variance		Variance (vs Jul-03)	
WBS	Item	May-02	Mar-03	Jul-03*	Feb-04	Dec-04	Estimate	$	%	$	%
4.1.1	Instrument Management	11,602	15,357	15,502	15,945	16,911	17,647	736	4.4%	2,145	13.8%
4.1.2	System Engineering	4,647	6,453	6,588	6,601	7,047	7,618	571	8.1%	1,030	15.6%
4.1.4	Tracker	9,877	10,915	13,595	14,698	17,126	19,927	2,801	16.4%	6,332	46.6%
4.1.5	Calorimeter	17,348	17,830	22,648	22,103	22,022	23,060	1,038	4.7%	412	1.8%
4.1.6	Anticoincidence Detector	10,280	11,557	13,870	14,022	15,595	17,241	1,646	10.6%	3,371	24.3%
4.1.7	Electronics, Data Acquisition, Flight Software	15,738	16,672	18,733	20,350	22,238	28,524	6,286	28.3%	9,791	52.3%
4.1.8	Mechanical Systems	11,850	10,373	13,384	13,478	14,179	15,840	1,661	11.7%	2,456	18.4%
4.1.9	Integration & Test	6,654	6,588	6,384	7,373	8,013	9,451	1,438	17.9%	3,067	48.0%
4.1.A	Performance & Safety Assurance	2,180	1,607	1,486	2,469	2,935	3,844	909	31.0%	2,358	158.7%
4.1.B	Instrument Science Operations Center	2,552	2,512	326	328	328	336	8	2.4%	10	3.2%
4.1.C	Education & Public Outreach	2,598	2,684	2,448	2,448	2,448	2,684	236	9.6%	236	9.6%
4.1.D	Science Analysis Software	3,328	3,595	3,220	3,243	3,019	3,069	50	1.6%	(151)	-4.7%
4.1.E	Suborbital Flight Test	1,321	1,321	1,321	1,325	1,325	1,325	0	0.0%	4	0.3%
4.1	**Budget at Completion**	**$99,973**	**$107,462**	**$119,504**	**$124,383**	**$133,187**	**$150,566**	**$17,379**	**13.0%**	**$31,062**	**26.0%**
4.1	**Contingency**	**$21,266**	**$14,251**	**$14,345**	**$12,447**	**$2,798**	**$5,419**	**$2,621**	**93.7%**	**($8,926)**	**-62.2%**
4.1	**Total Estimated Cost**	**$121,239**	**$121,713**	**$133,849**	**$136,830**	**$135,985**	**$155,985**	**$20,000**	**14.7%**	**$22,136**	**16.5%**

* Implemented in the LAT project control system, and first status reports, November 2003