GEM TN-91-00007

Independent Cost Estimate of the Spaghetti Hadron Calorimeter

F. Ayer, C. Elder, D. Sullivan, E. Womble

September 5, 1991

Abstract:

The Draper Laboratory, Inc. is providing independent estimates of the costs to build a scintillating fiber Hadron calorimeter for the Gamma Ray, Electron and Muon (GEM) detector. The estimates are a result of earlier studies of the TEXAS and Empact/TEXAS calorimeters, as well as quotes from vendors, and a careful examination of the calorimeter design, fabrication, assembly and testing requirements. An attempt was made to explore design modifications and opportunities to reduce the total cost of the calorimeter. In this report, 3 alternatives were evaluated yielding costs of $77M, $68M and $57M. As the cost is reduced; design, fabrication and material selections affect design complexity and implementation issues that are accounted for by different labor estimates. Contingencies of 10% on materials and 25% on other costs (since they are more difficult to estimate) have been used.

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INDEPENDENT COST ESTIMATE OF THE SPAGHETTI HADRON CALORIMETER

by

C.S. Draper Laboratory Inc.
Cambridge, MA

5 September 1991

F. Ayer
C. Elder
D. Sullivan
E. Womble

CSDL APPLICABLE EXPERIENCE

- Non-profit Research & Development Corporation
- 50 years of design, development and prototype fabrication experience
- 50 years experience transferring technology to industrial contractors
- Industrial engineering consultant to high volume industries: automotive, electronics
- Developer of industrial automation techniques and equipment for high volume applications: automation, apparel

DRAPER LABORATORY

DRAPER EXPERIENCE WITH TEXAS ET AND GEM COLLABORATIONS

• May - Aug '90	Scintillator Calorimeter Support Structural Design and Evaluation
• Sep - Dec '90	Tower Manufacturing and Costing for Scintillating fiber Calorimeters
• Feb - May '91	Supertower Prototype Development and Casting
• Aug '91	GEM Fiber Calorimeter Cost and Structural Analysis

DRAPER LABORATORY

CALORIMETER COST REDUCTION

- Fewer/larger towers
- Trade high labor costs for materials
- Build precision into tools
- Use of foundry type procedures/costs/efficiencies not skilled labor
- Apply automation where practical

DRAPER

COST ANALYSIS APPROACH

- Cost analysis format is derived from ORNL spread sheet
- Our unit costs are based on discussions with ORNL, BU, collaboration physicists (Hans Paar) and vendors for fibers, lead, steel, and fabrication.
- We present 3 cost analyses:

  A. Nominal design with new fiber cost and new contingency rationale

  B. Same as "A" but used 50% lead shot and a slightly smaller calorimeter

  C. Same as "B" with reduced physics segmentation

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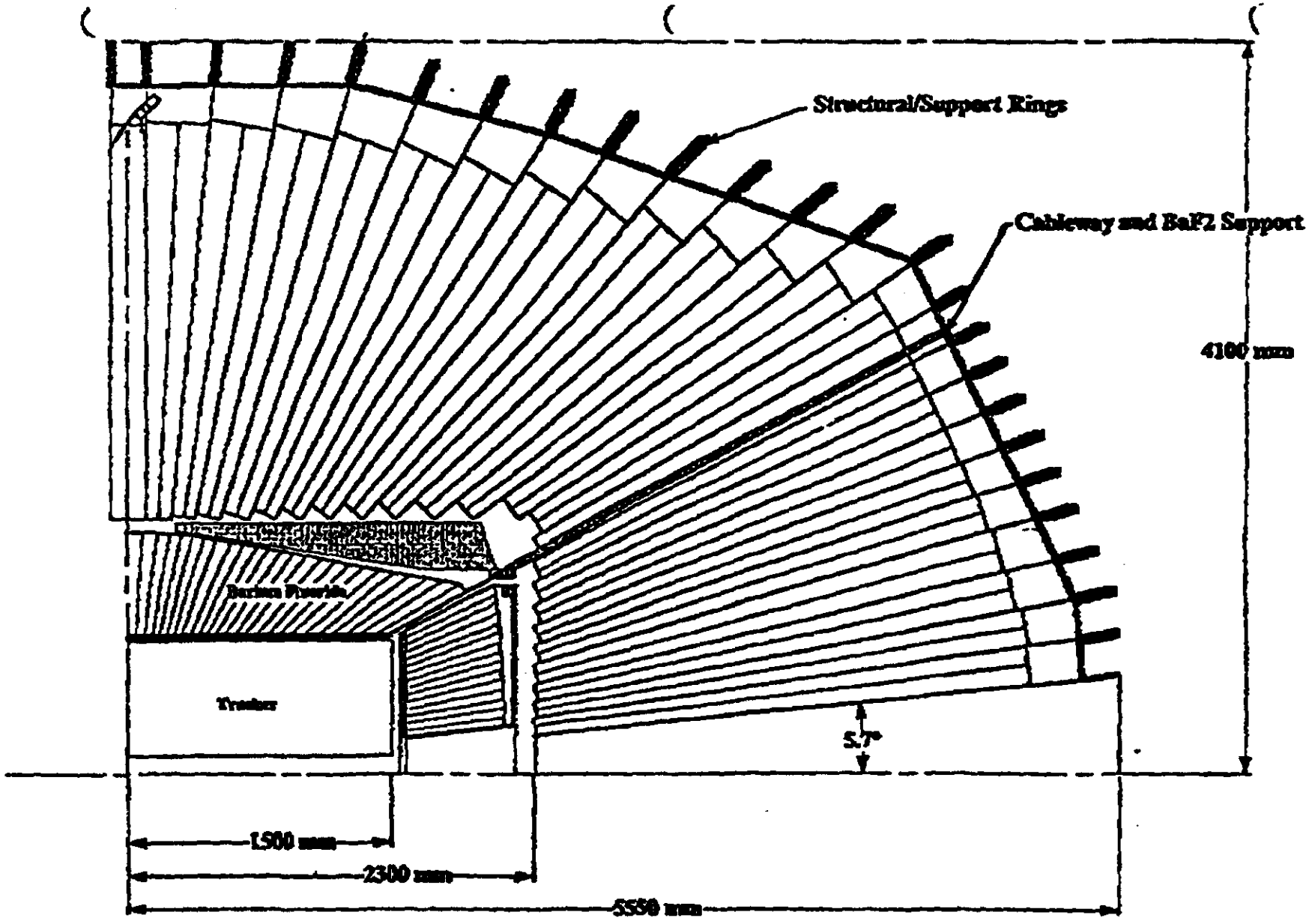


Spaghetti Hadron Calorimeter
Barium Fluoride EM Calorimeter

LS.93.SC.00037

Rennich

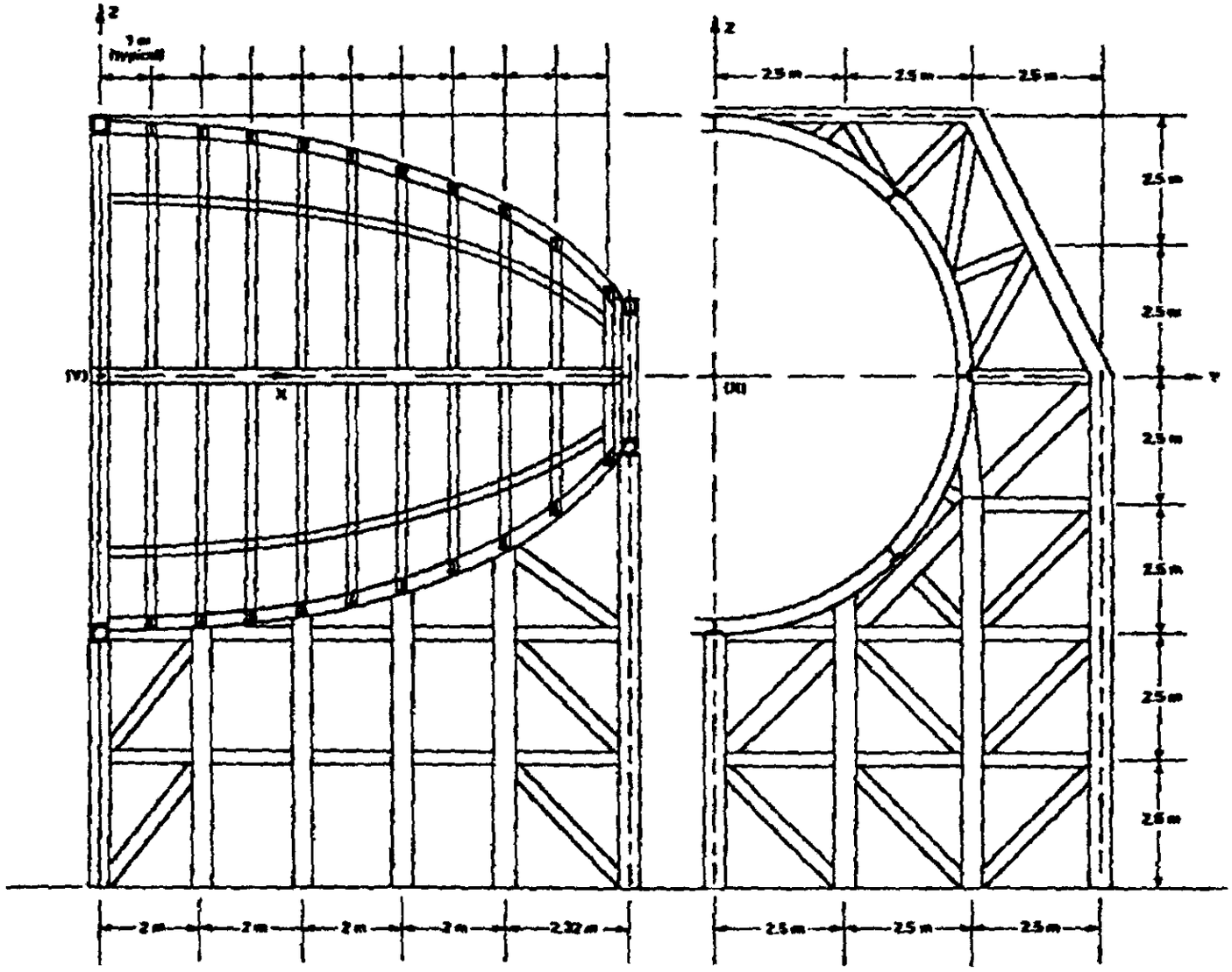
GEM Calorimeter Structures

The structural weight is estimated by extrapolation from our Texas calorimeter design, analysis, and evaluation (Aug. 90).

Texas Calorimeter		GEM Calorimeter	
• Ellipsoidal	20m long dia 10m short dia	"Ellipsoidal"	11m long dia 8m short dia
• Towers	Volume 753 m^3	Volume	273 m^3
• Structures	Tons		Tons
Shell Plate(2cm)	80	Plate (1.5cm)	30
Rings Circumfer.	64	Rings	25
and Longitudinal Supporting Frames	174	*Support to membrane	30
	318 Tons		85 Tons = 187,000 lbs

* The present design assumes a central membrane to support the calorimeter structure in the middle. Special structural members are required for a stable attachment. Our estimate is 30 tons.

TEXAS CALORIMETER – STRUCTURAL SYSTEM



MATERIAL QUOTES

- **Fibers 3mm scintillating type RH-1**

  Bicron Corp.

  Quoted 7,600,000 for 6000km of fiber

  includes: fiber, trimming, heading, inserting into spacer plates, boxing, shipping, and wastage

  Contingency: Bicron suggests no more than 10%

  Note that this represents $1.27/m with labor previously counted in tower construction

  See attached Bicron letter for details.

- **Stainless Steel**

  Ryerson, Allston Ma, new line

  Quoted $2/lb. for 304 type ST. steel

  Used $5/lb for structural system and sheaths to account for fabrication processes. Contingency should be no more than 10%.

- **Lead Shot**

  Tarcorp Industries, Granite, Illinois

  Quoted $0.45/lb for dust shot of 0.6mm dia. average.

  Produces 30m lbs/year of lead shot

  Contingency should be no more than 10%

GEM DETECTOR

SCINTILLATING FIBER HADRON CALORIMETER

COST ANALYSIS A

	Category	Tot Uts	$K Unit	Units	Costs $K
1.00	Towers				
1.10	Lead	2126	5.58	Mton	$11,855
1.20	Fiber	6.00E + 06	.00127	Meters	$7,600
1.30	PMT's	13232	0.30	Each	$3,970
1.40	Sheaths + Cover Plate	3308	.40	Each	$1,323
1.50	Light Guides	13232	0.10	Each	$1,323
1.60	Spacer Plates	3308	0.20	Each	$662
2.00	Electronics	13232	0.25	Channels	$3,308
3.00	Structure	187,000	0.005	LBS	$935
4.00	Thermal Cont				$500
5.00	Fab & Ass.				
5.10	Fab. Ass. & Test	15.8	0.045	M-H/tower	$9,380
5.20	Tooling				$3,000
6.00	Testing				
6.10	Test Beam				$1,000
6.20	Test Equip				
7.00	Transport				$500
8.00	Installation				
8.10	Install. Labor	17,000	$45/MH	Man-Hour	$765
8.20	Install. Equip				$1000
DIRECT COST					$47,121
EDIA		25%			$11,780
BASE COST					$58,901
CONTINGENCY*		25%, 10%			$10,654
SUBTOTAL					$69,555
R&D		11%			$7,651
TOTAL					$77,206

*Contingency: 10% on lead, fiber, and steel
25% on other items

GEM CALORIMETER

SCINTILLATING FIBER HADRON CALORIMETER

COST ANALYSIS B

	Category	Tot Uts	$K Unit	Units	Costs $K
1.00	Towers				
1.10A	Ostalloy 50%	948	5.58	Mton	$5,290
1.10B	Lead Shot 50%	1139	.99	Mton	$1,128
1.20	Fiber	5.7E + 06	.00127	Meters	$7,239
1.30	PMT's	13232	0.30	Each	$3,970
1.40	Sheaths + Cover Plate	3308	.40	Each	$1,323
1.50	Light Guides	13232	0.10	Each	$1,323
1.60	Spacer Plates	3308	0.20	Each	$662
2.00	Electronics	13232	0.25	Channels	$3,308
3.00	Structure	160,000	0.005	LBS	$800
4.00	Thermal Cont				$500
5.00	Fab & Ass.				
5.10	Fab. Ass. & Test	15.8	0.045	M-H/tower	$9,380
5.20	Tooling				$3,000
6.00	Testing				
6.10	Test Beam				$1,000
6.20	Test Equip				
7.00	Transport				$500
8.00	Installation				
8.10	Install. Labor	17,000	$45/MH	Man-Hour	$765
8.20	Install. Equip				$1000
DIRECT COST					$41,188
EDIA		25%			$10,297
BASE COST					$51,485
CONTINGENCY*		25%, 10%			$9,912
SUBTOTAL					$61,397
R&D		11%			$6,754
TOTAL					$68,151

*Contingency: 10% on lead, fiber, and steel
25% on other items

GEM CALORIMETER

SCINTILLATING FIBER HADRON CALORIMETER

COST ANALYSIS C

	Category	Tot Uts	$K Unit	Units	Costs $K
1.00	Towers				
1.10A	Ostalloy 50%	948	5.58	Mton	$5,290
1.10B	Lead Shot 50%	1139	.99	Mton	$1,128
1.20	Fiber	5.7E + 06	.00127	Meters	$7,239
1.30	PMT's	3308	0.30	Each	$992
1.40	Sheaths + Cover Plate	3308	.40	Each	$1,323
1.50	Light Guides	3308	0.20	Each	$662
1.60	Spacer Plates	3308	0.20	Each	$662
2.00	Electronics	3308	0.25	Channels	$827
3.00	Structure	160,000	0.005	LBS	$800
4.00	Thermal Cont				$500
5.00	Fab & Ass.				
5.10	Fab. Ass. & Test	15.8	0.045	M-H/tower	$9,380
5.20	Tooling				$3,000
6.00	Testing				
6.10	Test Beam				$1,000
6.20	Test Equip				
7.00	Transport				$500
8.00	Installation				
8.10	Install. Labor	17,000	$45/MH	Man-Hour	$765
8.20	Install. Equip				$1000
DIRECT COST					$35,068
EDIA		25%			$8,767
BASE COST					$43,835
CONTINGENCY*		25%, 10%			$8,000
SUBTOTAL					$51,835
R&D		11%			$5,702
TOTAL					$57,537

*Contingency: 10% on lead, fiber, and steel
25% on other items

SUMMARY

- Calorimeter design, fabrication, assembly, and testing are still preliminary and evolving.
- Cost estimates are based on realistic enquiries (quotes) to specialists and vendors.
- Quantities (lead, fiber) have been checked and structural system is based on sound previous work.
- Contingencies for materials (10%) reflect vendors inputs.
- Other costs (labor, tooling, testing etc.) are more difficult to estimate and a higher (25%) contingency is appropriate.

CSDL

FAX TO: CHARLES STARK DRAPER LABORATORIES
ATTN: FRANCOIS AYER
FROM: CHUCK HURLBUT, BICRON CORPORATION
DATE: 5 SEPTEMBER 1991

SUBJECT: BUDGETARY PROPOSAL FOR SCINTILLATING FIBERS FOR THE "GEM" COLLABORATION.

This estimate is for budgetary purposes. It represents the work of several people at Bicron including myself, the two senior engineers which have been assigned to our fiber program for the last three years, our Engineering Manager and our accounting department. We consider this to be a serious estimate with a high degree of accuracy.

We propose to provide the following goods and services:

6,000,000 meters of 3 mm dia. Type RH-1 scintillating fibers cut and assembled into 3,124 "preform" subassemblies as described below.

Total Price: $7,600,000
FOB Newbury, Ohio

The preforms would consist of 3600 individual fibers inserted into a set of precision drilled metal plates. The hole pattern would be a 60 x 60 matrix. The set of plates would be close stacked together resembling a single unit without spaces between the layers. The fibers would be precision cut to various lengths depending on their position in the assembly. The central fibers would be the maximum length, and the fibers would be shorter as their position is closer to the edge of the array. The final assembly would resemble a truncated pyramid. One end of each fiber would be modified to a slightly larger diameter too prevent its falling through its hole when the assembly is held so the fibers hang vertically with the larger end of the array at the top. The longest fiber in each preform would be about 220 cm Each preform would be packaged in an individual wood crate with the precision plate stack still in its condenced configuration.

Delivery would take about twenty months with the first assemblies being shipped about five months after receipt of order.

<u>CONDIFENCE IN MASS PRODUCTION COST EFFICIENCY</u>
Bicron has recently completed an SBIR Phase II development project in which the major task was the development of a mass production system for manufacturing large quantities of scintillating and waveguide optical fibers for use in the SSC. Main elements of this investigation included the following:

- Total factory layout
- Large volume monomer purification and storage
- Polymerization system design to achieve high throughput and quality consistency
- High speed fiber fabrication

Major prototype process equipment was constructed and successfully operated, and some components for the final operation were procurred.

Our estimates of the various cost factors in this proposal are based on our experience from the SBIR work which is now being continued with Bicron internal funding.

MAJOR COST ELEMENTS IN THE PROPOSAL

A. Raw Materials: Allowances were made for all forseeable efficiency problems including potential impact of international tensions affecting petroleum supplies and unpredictable difficulties in starting up the full volume system required for this program.

B. Labor: A full independent factory operating around the clock is envisioned. Personnel considerations included such factors special maintenance staff, dedicated management, training expenses, and impact of efficiencies on total labor required.

C. Factory Overheads: All standard and special factory overheads for the entire time of dedicated operation were included. All costs were accumulated in a zero-based calculation.

D. Special Factory Equipment Costs: A major portion of the factory construction expenses are allocated against this project. Reasons for this include the fact that the factory as constructed will be highly specialized with very little opportunity for cost recovery aside from special SCC projects like this one. A second reason is that a special set of equipment for assembly of the "preforms" will be constructed with the particular costs fully allocated here.

E. Special Preform Assembly Equipment: The concept for this equipment is already well developed as the outcome of a meeting of four members of the Bicron technical staff, each person having over 20 years in manufacturing process design from a variety of backgrounds. Each instrument would inspect the fiber as it is made on the continuous fiber lines and reject it if appropriate. Good fiber would be cut to the appropriate lengths, inserted in the appropriate holes, and altered to have a large "head". It would be a computer controlled system. Three systems would be constructed with one kept in reserve for breakdowns.

ADDITIONAL CONTINGENCIES

Contingencies that SSC planners prefer to add on need not exceed ten percent since significant contingencies have been factored into the above prices.