9. Costs and Schedules

The development of credible cost estimates for the construction of the CANDLE facility requires an assessment of the technical capability of Armenian industry to provide for the needs of the project. Included also is the need to understand in detail the cost structure in the country, particularly in the area of personnel. We have decided to adopt an approach in which the project is broken down in a manner schematically shown in the following diagram (Fig. 9.1) with accompanying Tables. As seen from the Figure, we have attempted to develop the costs in some detail.

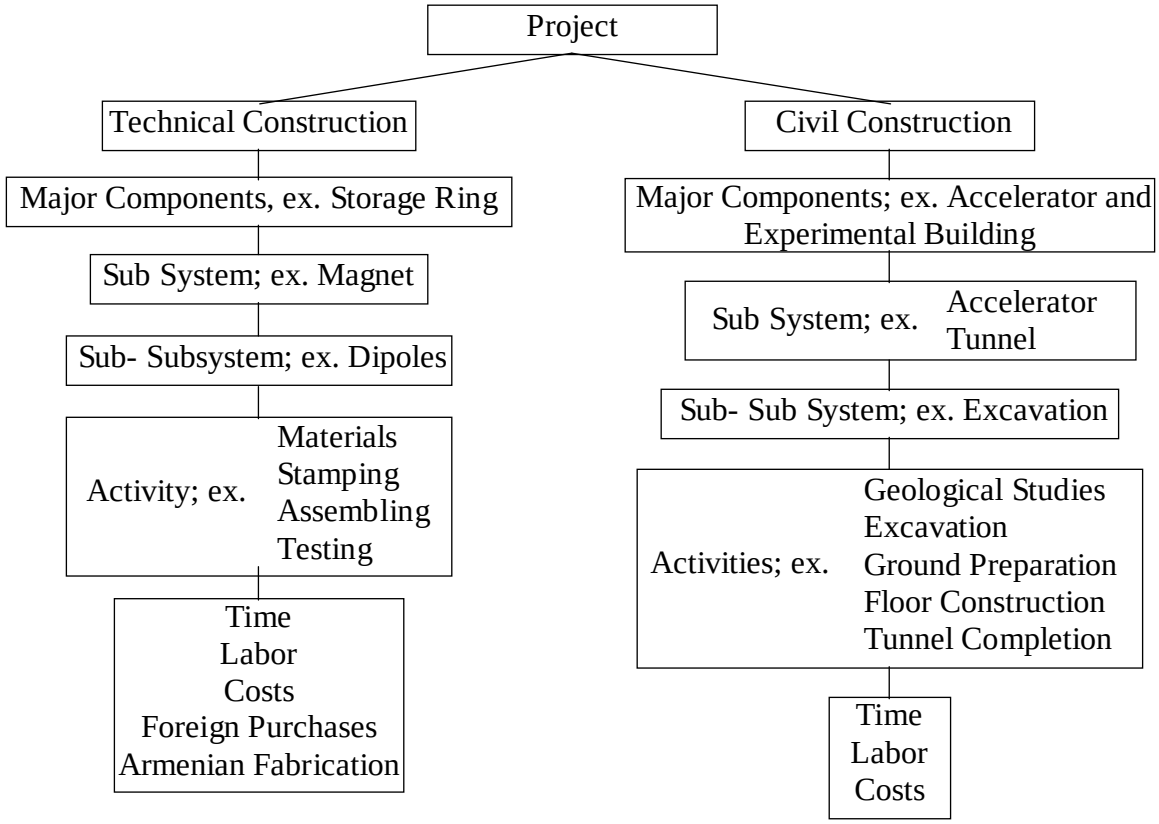

Fig. 9.1.

A number of general but important features need to be understood in attempting to assess the accuracy of the cost estimates which have been derived including the following:

- Much of the fabrication of components will be performed in Armenia. This expectation will be based upon an in depth study of particular industrial firms. This policy is consistent with the requirement of a high level of technical capability in Armenia together with the desire to provide a benefit to the Armenian economy at no additional cost to the project.
- Where our assessment indicates that highly specialized components such as r. f. equipment such as r. f. cavities and klystrons or sophisticated beam monitoring equipment cannot be expected to be provided by Armenian industry, purchases from foreign firms is indicated. Where development of fabrication techniques is indicated,

such as vacuum chamber development, such activity will be conducted at CANDLE facilities.

- Where applicable, wage scales prevalent in Armenia will be adopted. At the present time, those levels are at a level of about one-tenth of those in Western Europe and the U. S. This factor is extremely important to remember in making a comparison of the cost of CANDLE with comparable facilities abroad such as, for example, SPEAR III.

9.1. Project Cost

The cost of construction of the facility will be 48.0 million U. S. dollars (2002). The estimate involves the main components of the complex including storage ring, booster, linac and transfer lines, accelerator tunnel, two experimental halls, assembly area, control room, cooling plants, water and power distribution systems, and five instrumented beam lines. The office complex already exists in the form of a 6900 m^2 area building provided for CANDLE use for a period of 50 years by the Armenian government. A 20 hectare plot of land has additionally been provided by the Armenian government to house the accelerator elements and experimental beam lines.
Upon completion of the facility, operational costs will amount to about 4 million USD on an annual basis. A staff of about 110 will be required.
We discuss now in more detail the items previously alluded to. Table 9.1.1 is a breakdown of the total cost of 48.0 million dollar for the project, together with the percentages of the total cost.

Table 9.1.1 Cost estimates for the primary components

#/#	ITEMS	Cost (k$)	%
0	DESIGN	800	1.7
1	**S-band LINAC**	3,000	6.25
2	LINAC-to-BOOSTER TRANSFER LINE	660	1.4
3	BOOSTER	5,640	12
4	BOOSTER-to-STORAGE RING TRANSFER LINE	880	1.8
5	STORAGE RING	12,590	26.2
6	SAFETY (Electrical and radiation safety interlock subsystems, portable and fixed monitors. Safety Shielding not included)	500	1.0
7	BEAM LINES (5)	9,600	20
8	MAIN BUILDING (Safety Shielding & Contingency included)	6,100	12
9	CONVENTIONAL FACILITIES	2,000	4
10	COMISSIONING	370	0.8
11	CONTINGENCY** (Prototypes, Test Facilities, Spare Parts etc)	6,260	13.0
	TOTAL	**48,000**	**100.0**

* Preliminary. Salaries included.
** Without of the Main Building Contingency

Tables 9.1.2 to 9.1.5 give the breakdown costs for the components of the accelerator facility.

TABLE 9.1.2 Storage ring

#/#	ITEM	DESCRIPTION	COST(k$)
1	Magnets (Power Supplies Included)	80 Quadrupoles, 32 Dipoles, 64 Sextupoles, 64 Orbit Correctors	3,150
4	RF System (Power Supplies Included)	Cavities, Klystrons, Waveguides, Feedback & RF Low Power Drive, RF Control, etc.	3,400
5	Diagnostics & Control	Hardware and Software	940
6	Mechanical & Electrical	Supports, Cooling, etc.	1,600
8	Vacuum		3,500
	STORAGE RING (Subtotal)		12,590

Table 9.1.3 Booster

#/#	ITEM	DESCRIPTION	COST(k$)
1	Magnets (Power Supplies Included)	64 Quadrupoles, 48 Dipoles, 28 Sextupoles, 48 Correctors	1,970
2	Injection (Power Supplies Included)		100
3	Extraction (Power Supplies Included)		130
4	RF System (Power Supplies Included)	Cavity, Klystron, Waveguides, Feedback & RF Low Power Drive, RF Control, etc.	1,040
5	Diagnostics & Control	BPMs, BLMs, Thermometers, Scrapers, Analyzers, etc.	600
6	Mechanical	Supports, Cooling, etc.	900
7	Electrical		200
8	Vacuum		700
	BOOSTER (Subtotal)		5,640

Table 9.1.4 Linac

#/#	**ITEM**	**DESCRIPTION**	**COST (k$)**
1	S-band 100 MeV Linac*		3,000

* This item is under negotiation with another laboratory. The cost listed is that of a new linac contracted with an outside ventor and represents a maximal cost scenario

Table 9.1.5 Transfer lines

#/#	ITEM	DESCRIPTION	Cost (k$)
LINAC-to-BOOSTER TRANSFER LINE			
1	Magnets (Power Supplies Included)	9 Quadrupoles, 2 Dipoles, 1 Thick Septum, 1 Kicker	240
2	Vacuum		150
3	Mechanical & Electrical	Supports, Cooling, etc.	180
4	Diagnostics & Control		90
	LBTL (Subtotal)		660
BOOSTER-TO-STORAGE RING TRANSFER LINE			
5	Magnets (Power Supplies Included)	6 Quadrupoles, 3 Dipoles, 4 Septums	350
6	Vacuum		200
7	Mechanical & Electrical	Supports, Cooling, etc.	220
8	Diagnostics & Control		110
	BSTL (Subtotal)		**880**

Table 9.1.6 provides the breakdown for the Experimental Beam Lines.

Table 9.1.6 Beam lines (5)

#/#	Item	Cost (k$)	Comments
1	Insertion Devices	2,500	
2	Beam Line Optics & Experimental Stations	5,600	
3	Front Ends	1,500	
	TOTAL	**9,600**	

Table 9.1.7 provides the breakdown for the building costs while Table 9.1.8 details the Infrastructure costs.
Table 9.1.9 provides the first year operational costs based upon operating for 7400 hours annually with an efficiency of 85 percent.
Items related to personnel staffing and costs are given in Tables 9.1.10 and 9.1.11, which provide data on annual staffing levels during construction and the first year of operation. Table 9.1.12 provides an estimation of labor costs in relevant categories for the years of construction.
Finally, Table 9.1.13 provides a comparison of some relevant costs with selected synchrotron radiation facilities in the U. S., Canada, and Western Europe. Some of these facilities have been operational for some time while others are in a similar phase of construction.

Table 9.1.7 Main building (MB)

		Cost (k$)	Comments
1	MB's Site Preparation	150	
2	Basement & Floor (Total)	500	500 Reinforced concrete
3	Roof (Total)	1,100	Thermal Insulation Included
4	Walls (Total)	420	Thermal Insulation Included
5	Shielding (Linac + Transfer Lines + Booster + Storage Ring)	330	500 Reinforced concrete
6	Mechanical	1,300	Special plumbing & piping, civil plumbing &fixtures, fire protection, air distribution etc.)
7	Electrical	1,100	Power transmission, service and distr., personnel safety, communication, etc.
8	Connecting Tunnels	150	
9	Other	500	
	SUBTOTAL	5,550	
	Contingency	550	9%
	TOTAL	**6,100**	

Table 9.1.8 Infrastructure's Cost Estimate

		Cost (k$)	Comments
1	Site Preparation (General Plan)	100	Landscaping; roads; car parking, miscell.
2	Cooling Facilities	700	Influx-and-exhaust fan; water cooling plant; cold water machines; piping, etc
3	Electrical	800	Sub-station and distribution; cable plant; lightning guard; grounding, etc
4	Others	400	Storages; repair shops; fire protection, etc.
	TOTAL	**2,000**	

Table 9.1.9 CANDLE annual operation cost cost (7,400 h/year, 85 %) (First YEAR)

#/#	ITEM	Cost(k$)
1	Electrical Power (8,000kW × 7500 h)* and Water (0.005 m^3/h × 7500 h)**	2,100
2	General maintenance and improvements	400
3	Outside contracts and travel	500
4	Miscellaneous	100
8	Personnel***	950
	TOTAL	**4,050**

* 1 kW·h – 20 ArmDr -> 0.035 US $.

** 1 m^3 - 56 ArmDr (0.1 US$). Water consumption-0.005 m^3/h (max).
Water Flow –500 m^3/h (Total);

*** Only staff on regular positions

Table 9.1.10 CANDLE required personnel and salary in 2002-2006

(Design, Construction, Installation, Commissioning)

	YEAR				
Staff on Regular Positions (only)	2002	2003	2004	2005	2006
Scientists	8	13	17	19	21
Engineers	10	12	15	16	17
Technicians	5	10	16	21	25
Administration	5	7	8	9	9
Other	-	4	11	19	38
TOTAL	28	46	67	84	110
Salaries in US k$* (then year)	200	350	530	700	950
Salary/ person in US k$ (then year)	7.2	7.56	7.92	8.34	8.76

* Inflation 5% / year

Table 9.1.11 CANDLE Personnel

(Commissioning & First Year Operation)

Staff on regular positions	
Scientists (“brain team”)	21
Machine (operating personnel)	25
Beamlines (services of the first 5 beamlines only)	20
General technical services	29
Directorate, administration, central services, etc	15
TOTAL	**110**

Table 9.1.12 Labor rates for CANDLE (in US k$/month)

		Then Year				
#/#	Labor Categories	2002	2003	2004	2005	2006
1	Mechanical Engineer	0.55	0.58	0.61	0.65	0.68
2	Electrical Engineer	0.55	0.58	0.61	0.65	0.68
3	Mechanical or Electrical Designer	0.45	0.48	0.50	0.53	0.56
4	Coordinator	0.45	0.48	0.50	0.53	0.56
5	Physicist	1.0	1.05	1.1	1.16	1.20
6	Software & Hardware Engineer	1.0	1.05	1.1	1.16	1.20
7	Technician	0.45	0.48	0.50	0.53	0.56
8	Administrative Support	0.35	0.37	0.39	0.41	0.43
9	Consultants	0.8	0.85	0.9	0.95	1.0
10	Metrologist/Alignment	0.55	0.58	0.61	0.65	0.68
11	Precision Assembly	0.65	0.68	0.70	0.74	0.78
12	Cleaning/Plating Shop	1.1	1.15	1.2	1.25	1.30
13	Mechanical Fabrication and Welder	0.9	0.95	1.0	1.05	1.1
14	Plant Engineering	0.65	0.68	0.70	0.74	0.78
15	Labor Services	0.45	0.48	0.50	0.53	0.56
16	Carpenter	0.55	0.58	0.61	0.65	0.68
17	Electrician	0.55	0.58	0.61	0.65	0.68
18	Ironworker	0.5	0.53	0.56	0.59	0.62
19	Plumber/Pipefitter	0.6	0.63	0.66	0.70	0.74
20	Riggers	0.6	0.63	0.66	0.70	0.74
21	Management	1.0	1.05	1.1	1.16	1.20

Table 9.1.13

ITEM	**CANDLE**[A] (estimated)	**ALS**[B]	CLS[c]	ESRF[d]
Electron Energy (GeV)	3.0	1.9	1.5 (2.9)	6.0
Possible Beamlines	80	60	26	49
Visiting Researchers/Users	-	1200	-	3361
Construction Cost (in US M$)	48.7	99.5	113 (est.)	-
Annual Operating Cost (in US M$)	4.0	-	5.4 (est.)	68.0
Personnel	110	185	-	537
Personnel Salary /year (in US M$)	0.95	-	2.1 (est.)	36.0

[a] CANDLE. Technical Design Analysis (TDA), (http://www.candle.am/~TDA/)
[b] Lawrence Berkeley Laboratory, (http://www-als.lbl.gov/aboutals/alsquickfacts.html)
[c] Canadian Light Source, (http://www.cls.usak.ca/profile/background.shtml);
[d] European Synchrotron Radiation Facility (ESRF), Highlights 2000, pp 104-107

The anticipated and requested profile for the period of construction is detailed in Figure 9.2.1. The profile is a typical one and begins in the first year with an intensive prototype program costing 3.3 million USD. It peaks in the 2004 and 2005 years and ends in the year 2007. The Work Function and Expenditure is shown in Figure 9.2.2 together with milestone dates for commissioning of major components.

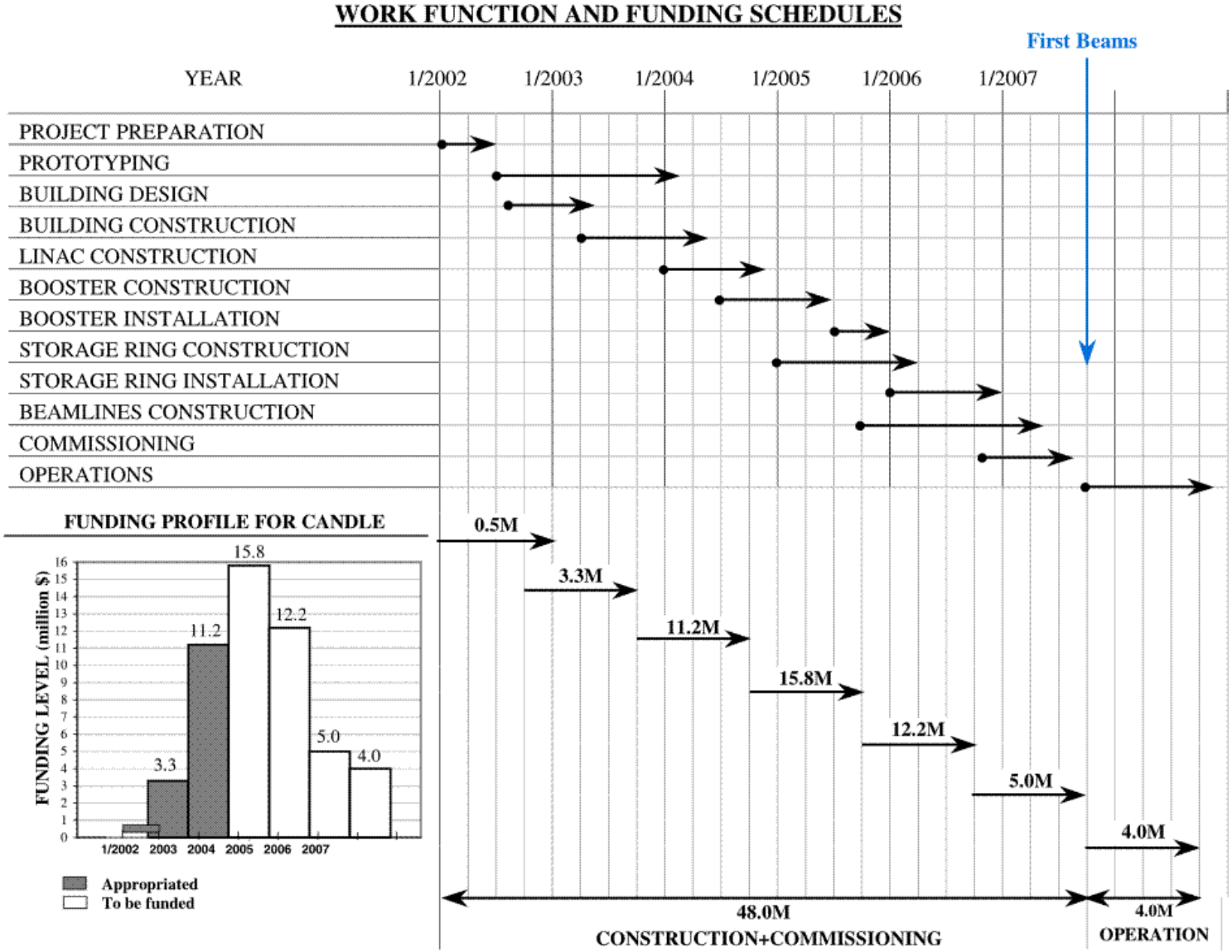

Fig. 9.2.1.

Fig. 9.2.2.

9.2 Project Implementation and Milestones.

Starting with the preliminary proposal on the CANDLE design study [1] in February 2001, the project got an approval in 15 of January 2002 for the preparation of the Technical Design Analysis which is the subject of the present report.
A very important stage of the CANDLE project development was the site consideration for the facility construction. After the study of the four potential sites located in capital of Armenia Yerevan, the site previously allocated for the Polytechnic Institute has been chosen most suitable for the New Facility construction. The site is distinguished by its location, the accessibility, the geological structure of the ground, nearby highway, flatness and the available area of about 70 hectares. An important feature of the site is the existence of 3-floor building with total area of 6900 m^2, which has been allocated by Armenian government for the CANDLE activity.
After preliminary renovation of the building in November 2001-January 2002, the part of the building has been occupied by the CANDLE team. Actually, the 100% of the present design report has been conducted already in the CANDLE office building. The major achievements during the period of 15 January – 1 July 2002 are

- The establishment of CANDLE core team of the scientists and engineers that can conduct the research and implementation of such a complexity facility;
- The creation of the world class working conditions in the office building, including the internet connection, that was the basis for the completion of Technical design study.
- An establishment of the collaboration with the number of research and educational institutions in Armenia (Yerevan Physics Institute, Yerevan State University) and abroad (SSRL and CAMD in USA, DESY and Technical University Darmshtadt in Germany, Institute of Microelectronics in Russia).
- An important stage became the user case development, the first stage of which is resulted on more than 60 proposals from different institutes in Armenia and abroad (France, USA, Russia).
- Presentation of the main design features of CANDLE in eight reports at the European Particle Accelerator Conference held in 3-7 June 2002 in Paris, France. In total, during past year have been published and reported at various conferences more than 20 publications on the CANDLE design and usage.
- An important stage is the agreement between CANDLE and Armenian Government on the usage of the building and the site allocation for the facility construction.

The design report of the CANDLE will be presented in July-August 2002 at the number of institutions in Armenia (Yerevan Physics Institute, Yerevan State University, National Academy of Science), in Russia (FIAN and Kurchatov Institute in Moscow, JINR in Dubna), in Germany (DESY and THD) and in a number of synchrotron light centers in USA (SSRL in Stanford , ALS in Berkley).
The year of 2002-2003 is planed to perform an extensive prototyping of facility main components (magnets, vacuum chamber) and to establish the laboratories on the magnets measurement, RF test stand, Control system, Beamline instrumentation and the Power supply system. In parallel will be developed the site geological study and the main building design. The CANDLE is scheduled for operation in September 2007. The construction and funding schedule profiles are presented in Fig. 9.2.1 and 9.2.2.