Some thoughts on Cost Estimating the LBDUSEL Water Cerenkov Detector

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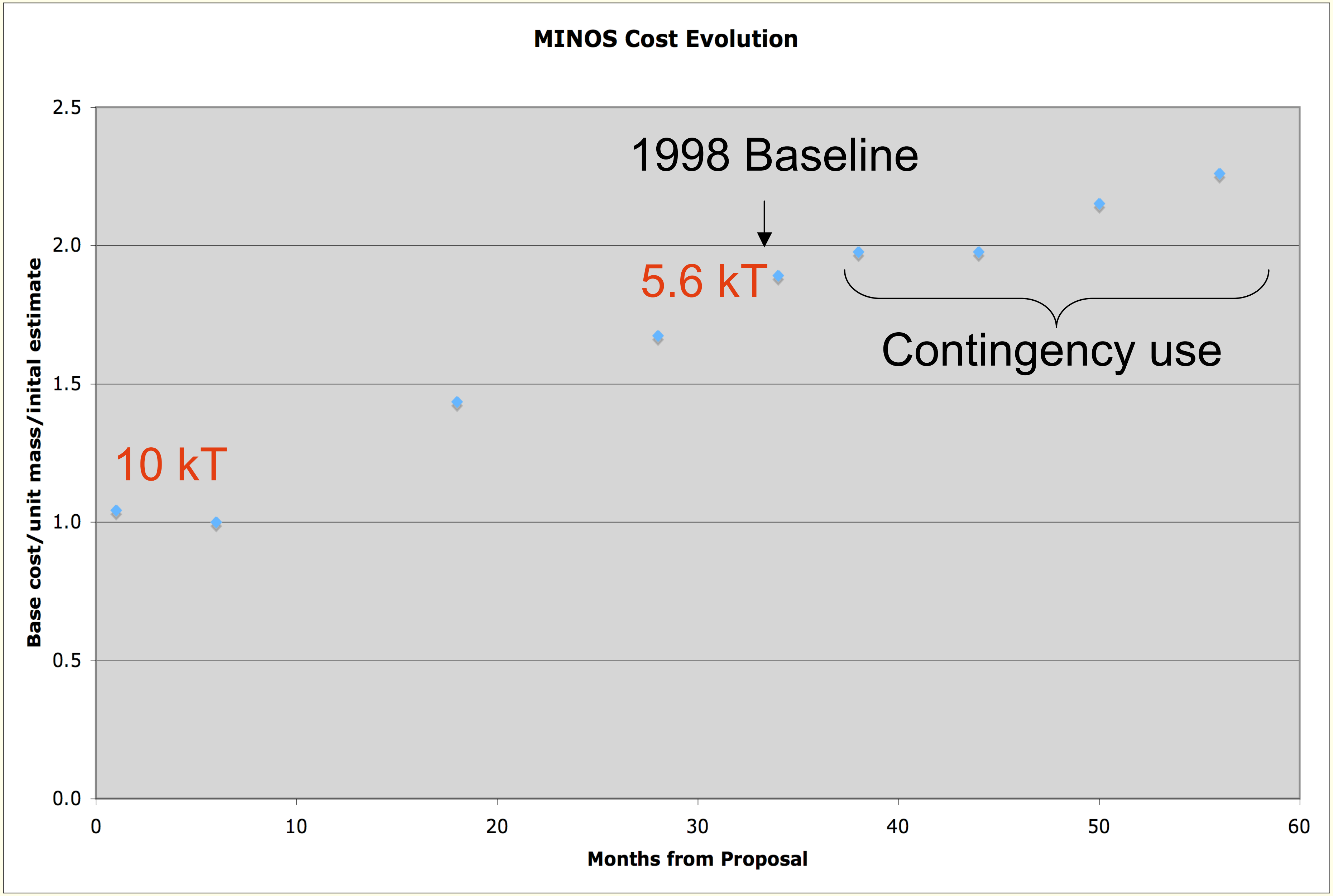
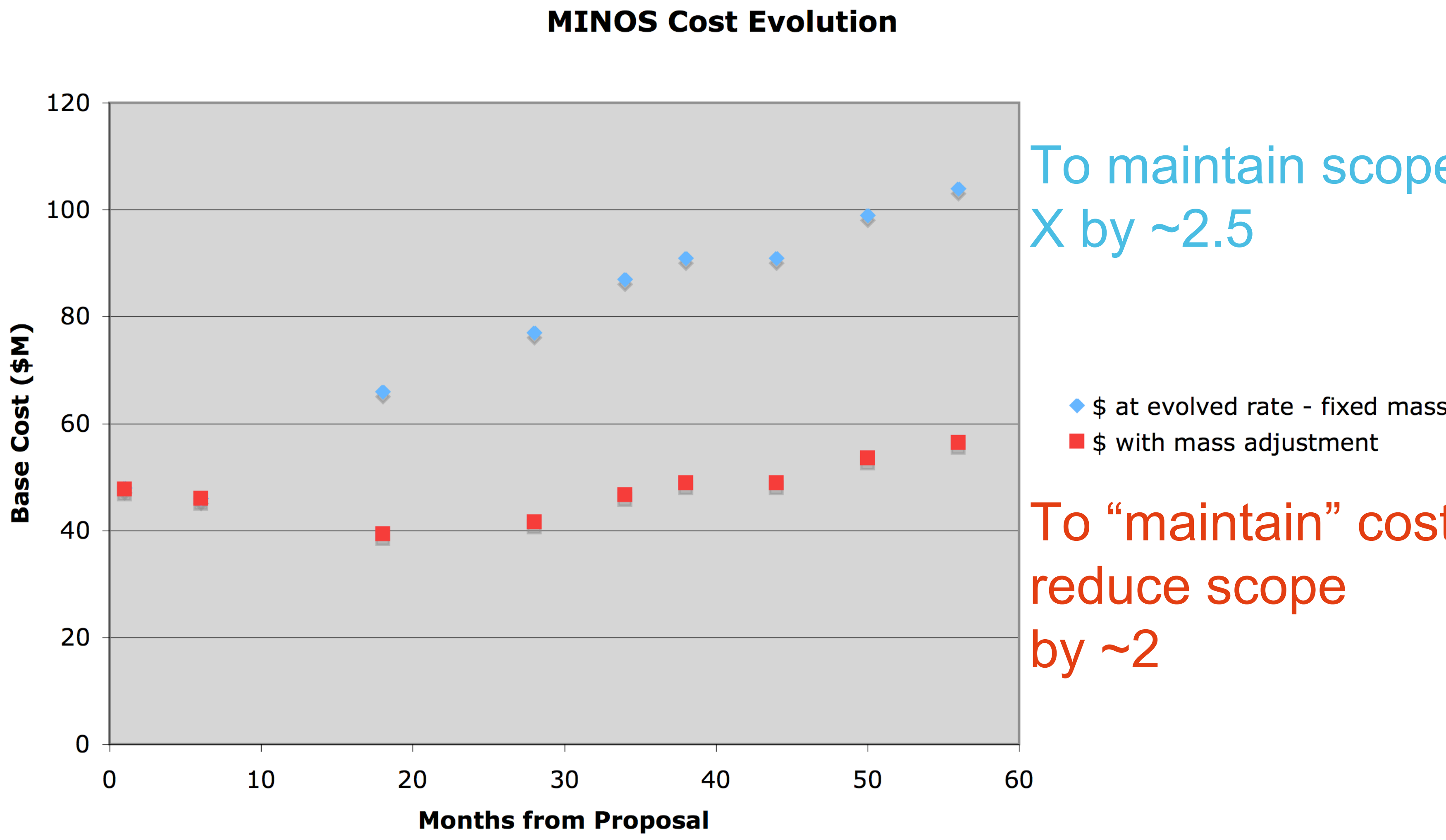
Contents

- Disclaimers
  - This material has been prepared for preliminary discussions only. There is a lot more work needed to be done!
  - It’s done using logic derived from my experience with other projects
  - Input data WELCOME
  - Fermilab is currently preparing cost estimates for Project X and Mu2e as well as LBDUSEL. We plan to come up with a set of standard numbers for inflation, SWF and overhead rates that will be applied uniformly to all projects, but has not been implemented yet.
    - This step may move the current results either up or down in cost….
    - Stay tuned

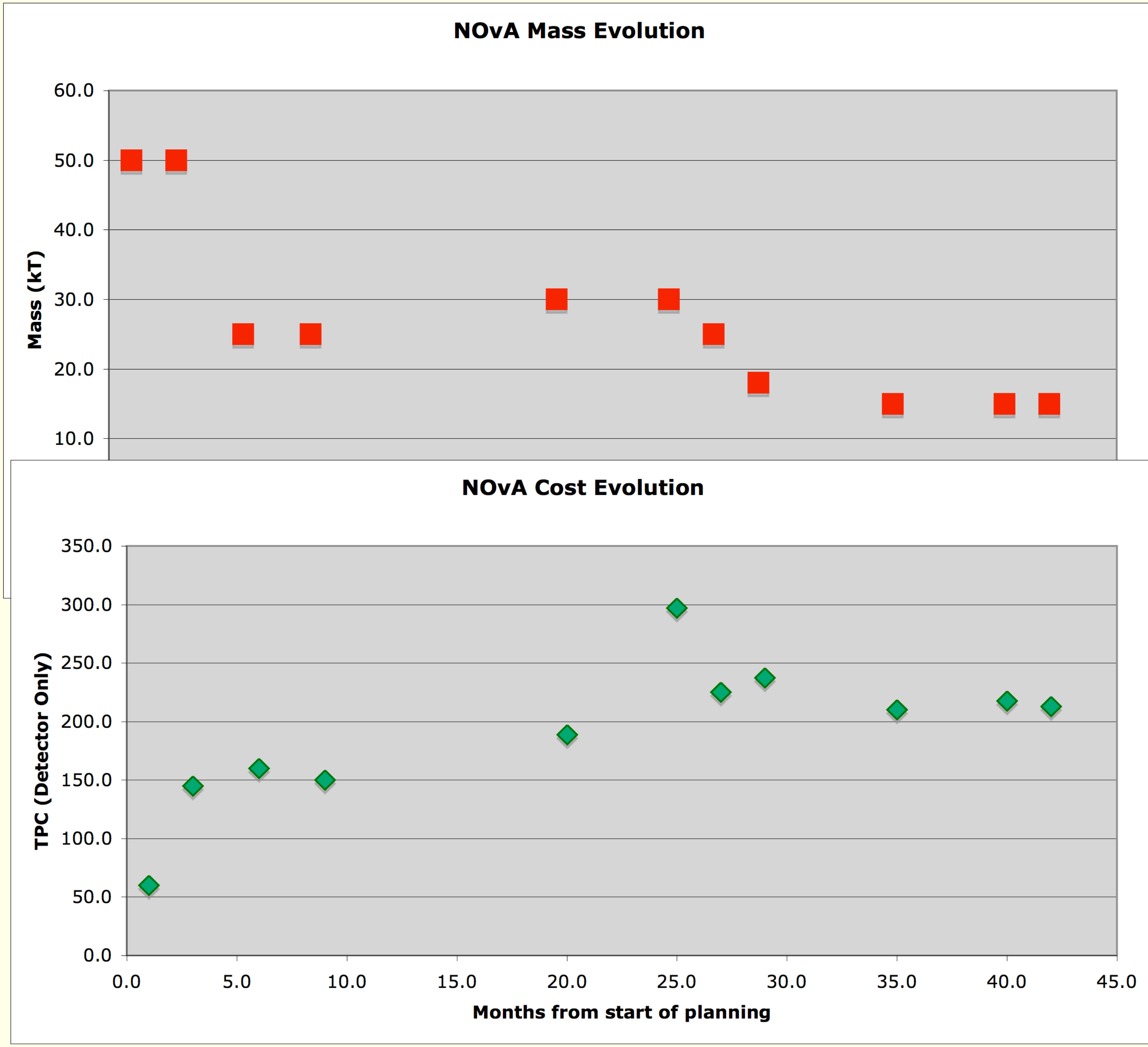
Examples of cost evolution from MINOS and NOvA


MINOS Cost Evolution
1998 Baseline
5.6 kT
10 kT
Contingency use
Base cost/unit mass/inital estimate
Months from Proposal
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60



To maintain scope X by ~2.5

To “maintain” cost reduce scope by ~2


NOvA Mass Evolution
Mass (kT)
60.0
50.0
40.0
30.0
20.0
10.0
NOvA Cost Evolution
TPC (Detector Only)
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
Months from start of planning

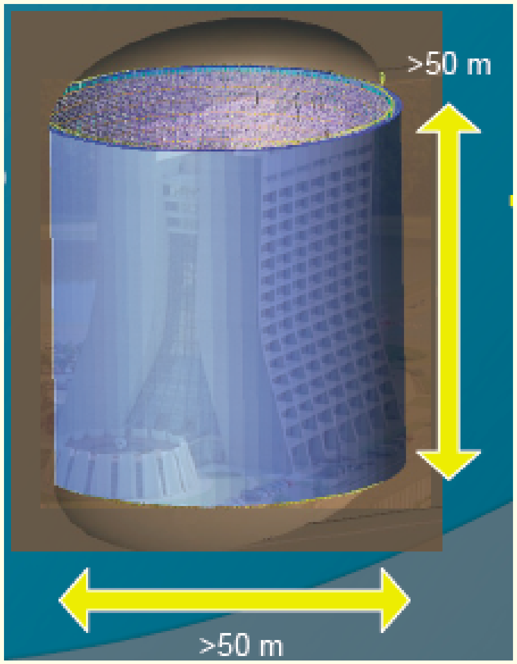
wn

We can not let this happen on this Project!

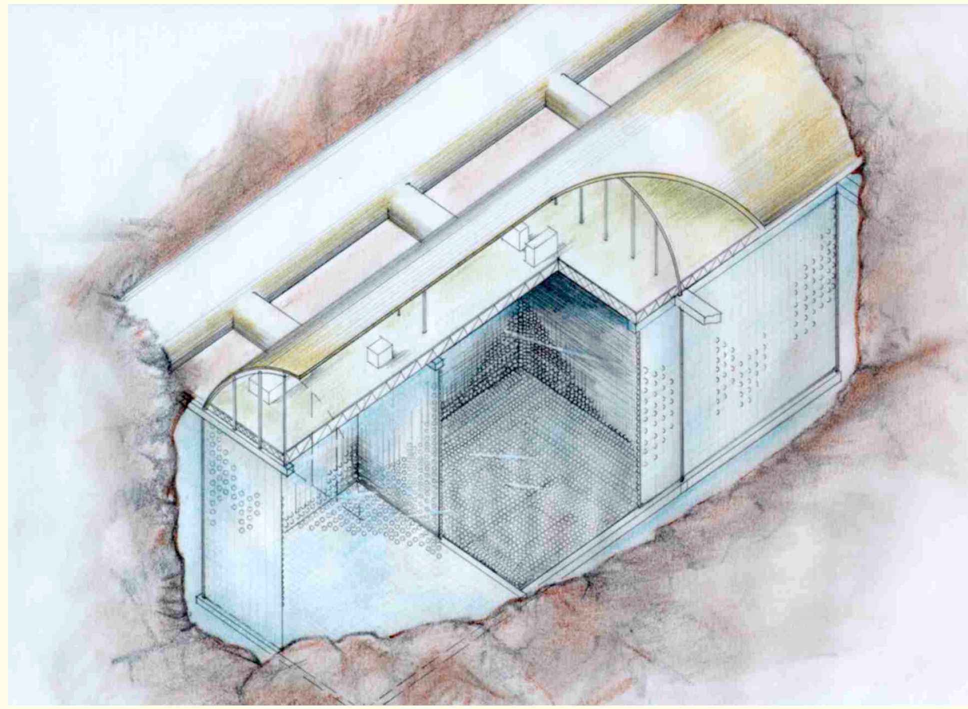
Large Water Cerenkov Detectors

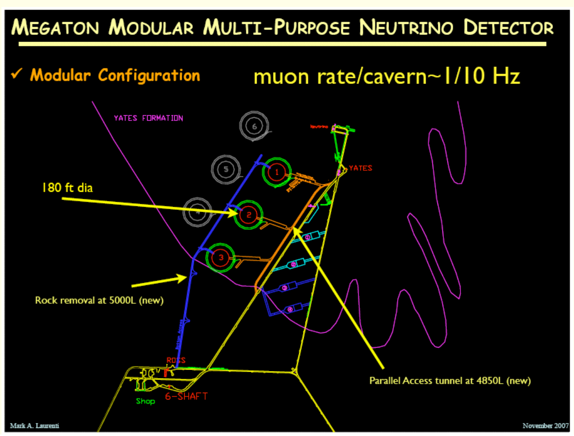
Detector Concepts

~100kT Fiducial Volume



~400 kT Fiducial Volume





Modular detector mass in multiple cavities
Vs. single large volume detector;
For modular : cylinder vs. “mailbox”

How much detector do we need at DUSEL?

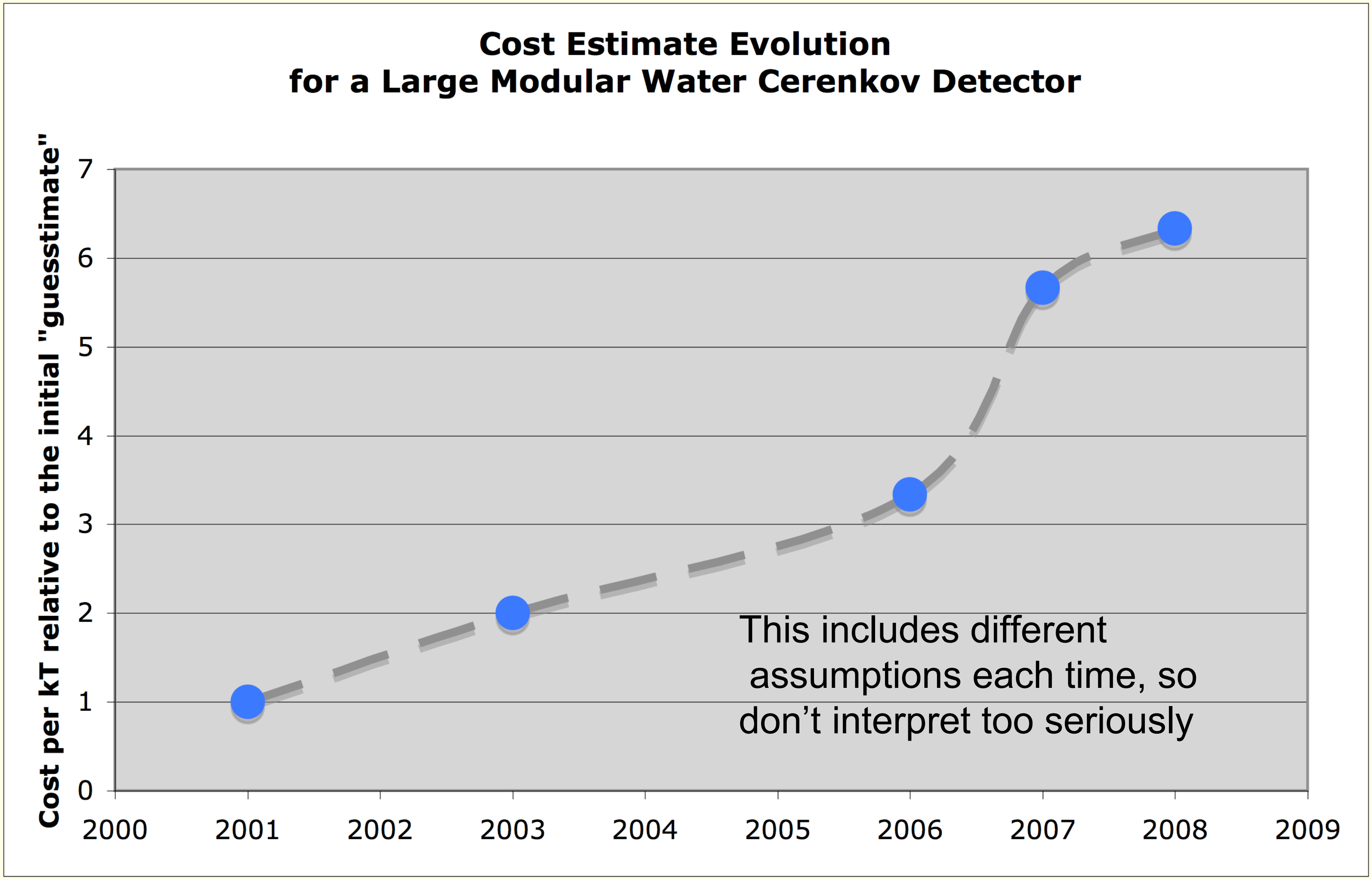
- Consider physics requirements for :
  - Neutrino oscillations
    - Theta 13, mass hierarchy, CP violation
  - Non-accelerator physics
    - Proton decay
    - Supernova bursts
    - *Relic supernovas*
    - *Solar neutrinos*
    - *Geoneutrinos*

We need to plan for at least 300kT

Cost estimate evolution (so far) of the modular WC detector

Documents supporting the cost estimate of the Homestake 3M proposal

Date	Document	Reference	Project Description	Cost Range	$/kT
July-01	Megaton Modular Multi-purpose Neutrino Detector	hep-ex/0108036	10 - 12 cavities to give ~1000kT mass; 20% PMT coverage	$150 M total for cavities; equivalent cost ($150M) for instrumentation;	0.3
October-02	Report of BNL Working Group (BNL-69395)	hep-ex/0211001	3 cavities	$44M total for 3 cavities	
June-03	Megaton Modular Multi-purpose neutrino detector for a Physics Program in the Homestake DUSEL	hep-ex/0306053	5 - 10 cavities; 14% PMT coverage	$17M/cavity (includes 15% contingency); ~$53M per instrumented module; 5 total modules < $300M	0.6
August-06	Prorosal for an Experimental Program in Neutrino Physics and Proton Decay in the Homestake Laboratory	hep-ex/0608023	3 100kT modules	$29M/cavity (includes rock disposal and 30% contingency); 25% PMT coverage; 3 Modules for $309M	1.0
June-07	Proposal for a very large water cherenkov detector	submitted to FNAL call for Project X era physics	1 - 3 chambers giving 500 - 1000 kT; >25% PMT coverage	~$400M Total	
February-08	Physics with a detector at Homestake	M. Diwan presentation to P5 (SLAC meeting)	1 100kT module	$28M for chamber construction (no rock disposal, no contingency); 1 module, 20% PMT coverage) including contingency : $27M R&D + $139M for 1st module ($166M for 100kT)	1.7
August-08	Update on construction from Mark Laurenti	Presentation to LBDUSEL ExComm meeting at FNAL	1 100kT size cavity	$29M excavation, no contingency, no disposal;add in 40% contingency and contractor overhead and ~$10M for rock disposal gives $87M per cavity	



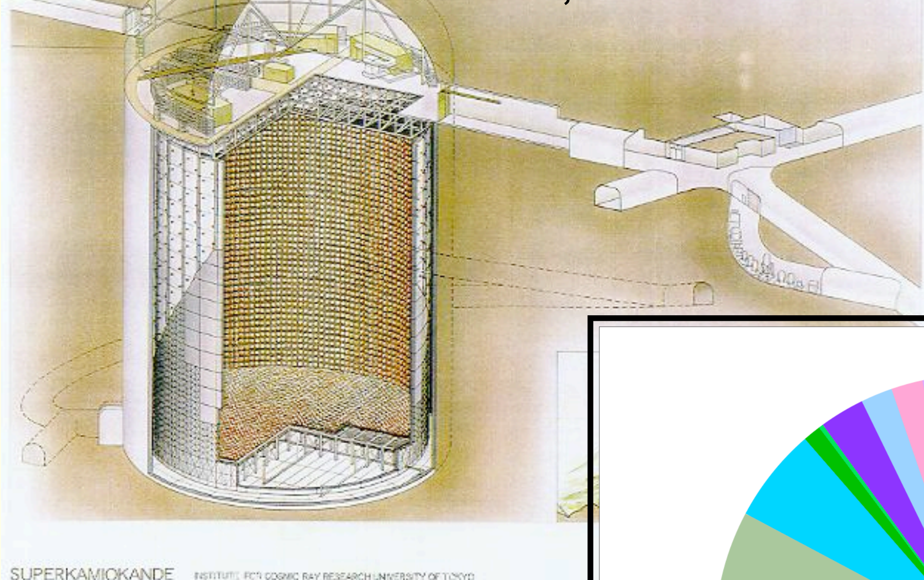
Cost Estimate Evolution
for a Large Modular Water Cerenkov Detector
Cost per kT relative to the initial "guesstimate"
0
1
2
3
4
5
6
7
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
This includes different
assumptions each time, so
don't interpret too seriously

Cost Drivers

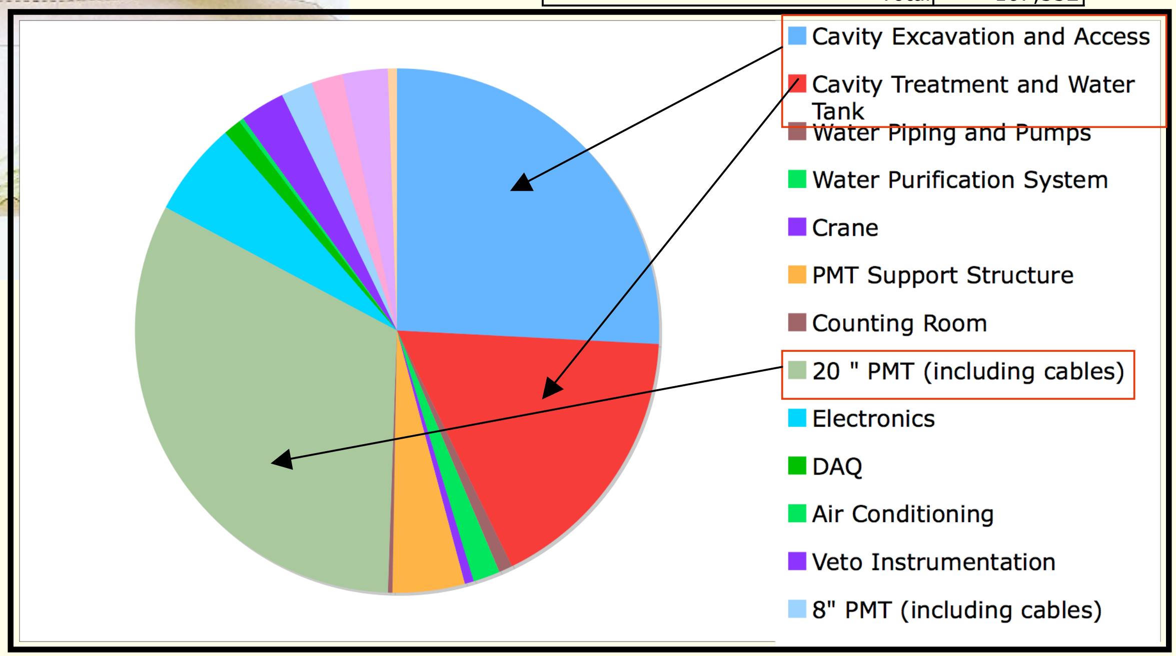
Super-K example

50 kT Total Volume

11,146 20” PMTs



	1996 K$
Cavity Excavation and Access	27,640
Cavity Treatment and Water Tank	18,400
Water Piping and Pumps	630
Water Purification System	1,850
Crane	760
PMT Support Structure	4,580
Counting Room	330
20 " PMT (including cables)	34,670
Electronics	6,330
DAQ	1,090
Air Conditioning	210
Veto Instrumentation	3,000
8" PMT (including cables)	2,262
Computer Building	1,860
Main Building	3,000
Power Station	720
Total	107,332



Cost Drivers

- Cavity and Infrastructure
- Instrumentation

Let’s analyze these separately for now….

Table 1. UNO Cost Estimates (in thousands of US dollars): This is a quite complete list of expense items for all aspect of detector construction. The "v" and "s" symbols note the volume-like and surface-like nature of cost scalings used when the costs are extrapolated from the Super-Kamiokande (SuperK) to UNO. A conversion rate of 1$ = 100 yen is used.

Item	SuperK		UNO
Cavity Excavation	27,640	v	168,000
Water piping and pumps	630	v	4,082
Water Purification Sys	1,850	v	11,988
Power Station	720	v	2,160
Crane	760	v	2,280
Water Tank	18,400	s	92,480
PMT support structure	4,580	s	23,019
Counting Room	330	s	990
Computer Building	1,860	s	2,232
Main Building	3,000	s	3,600
20″ PMT (including cables)	34,670	s	173,664
Electronics	6,330	s	9,495
DAQ	1,090	s	1,635
Air Conditioning	210	s	315
Veto instrumentation	3,000	s	9,000
8″ PMT (including cables)	2,262	s	17,881
Total	102,070		522,822

May 2000

Detector Instrumentation

$227M to instrument 450kT FV

→ 0.5M/kT → $50M/100kT

2007 Estimate for Modular Detector at Homestake

Summary cost ($FY07) for 300kT

Cavity construction (30% contingency)	$78.9M
PMT+electronics	$171.3M
Installation+testing	$35.7M
R&D,Water, DAQ, etc.	$8.2M
Contingency(non-civil)	$50.8M
Total	$344.9M

$215 M for instrumenting 300 kT FV

→0.72M/kT

→ $72M/100kT

M. Diwan - Project X workshop Nov. 2007

February 2008 (P5) discussion of costs (100kT FV)

Item	Cost	Source
Single Cavity construction	$28.1M*	Laurenti
contingency 30%	$8.4M	Preliminary Reviews
PMT(50000 chan)	$46.7M	Auger, NNN05, etc.
Electronics, cables	$10.65M	UPenn+SNO
Installation	$8.75M	Conceptual
Water, DAQ, testing, etc.	$11.4M	Quote, made for 300kT
Contingency(non-civil)	$25.0M	>30% for some items
Total	$139M	FY2007

* Cost and schedule reviewed by RESPEC, does not have rock disposal

$77.5 M for instrumenting 100 kT FV
→0.78M/kT
→ $78M/100kT

May 2000

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Air Conditioning	210	s	315
Veto instrumentation	3,000	s	9,000
8″ PMT (including cables)	2,262	s	17,881
Total	102,070		522,822

Cavity and Infrastructure

$185M to support 600 kT TV

→ 0.3M/kT → $30M/100kT

*based on $260/m³ excavation

2007 Estimate for Modular Detector at Homestake

Summary cost ($FY07) for 300kT *

Cavity construction (30% contingency)	$78.9M
PMT+electronics	$171.3M
Installation+testing	$35.7M
R&D,Water, DAQ, etc.	$8.2M
Contingency(non-civil)	$50.8M
Total	$344.9M

(wo contingency)

$60.7M for

375 kT TV

→0.16M/kT

→ $16M/100kT

Does not include rock disposal, OH&P…

M. Diwan - Project X workshop Nov. 2007

* 3 modules, FV/TV ~0.8

February 2008 (P5) discussion of costs (100kT FV)

Item	Cost	Source
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Installation	$8.75M	Conceptual
Water, DAQ, testing, etc.	$11.4M	Quote, ma
Contingency(non-civil)	$25.0M	>30% for
Total	$139M	FY2007

* Cost and schedule reviewed by RESPEC, does not have rock disposal

$28.1 M for 120 kT TV
→0.28M/kT
→ $28M/100kT

Closer agreement with the 2000 UNO estimate, However…

August 2008 discussion of chamber cost

SUMMARY OF CHAMBER EXCAVATION (2007 Dollars)

	# of Chambers	Cost [1]	TOTAL
Site Geotechnical & Modeling	3	$ 761,600.00	
Chamber Top & Btm Access	6	$ 4,331,054.29	
Excavate Chamber	1	$ 28,793,569.24	
	Sub Total	$ 33,886,223.54	**$ 33,886,223.54**
Equipment Ownership Cost		$ 10,020,000.00	
	Sub Total	$ 10,020,000.00	**$ 43,906,223.54**
ContractorOverhead 10%		$ 4,390,622.35	
Contractor Mark-Up 20%		$ 8,781,244.71	
	Sub Total	$ 13,171,867.06	**$ 57,078,090.60**
Contingency 40%		$ 22,831,236.24	
	Sub Total	$ 22,831,236.24	**$ 79,909,326.84**
	Tons		
Material Handling Cost At Shaft [2]			
Skipping cost $4.00 / Ton	501,585	$ 2,006,340.00	
Disposal cost $10.00 / Ton	501,585	$ 5,015,850.00	
	Sub Total	$ 7,022,190.00	**$ 86,931,516.84**

Note (1) 2007 Constant Dollars
Note (2) This is a rough estimate with little to no Back-up

wo contingency

$64.1 M for

120 kT TV

→0.53M/kT

→ $53M/100kT

Probably more realistic, but still needs a lot more work - does not include a liner or other infrastructure

Mark Laurenti

Let's start over….

WBS for WC Detector(s) at DUSEL

1.0 Civil Construction and Infrastructure
- **1.1 Chamber Excavation**
- 1.2 Chamber Liner
- 1.3 Infrastructure Systems
- 1.4 Life Safety Systems

2.0 Detector Instrumentation
- **2.1 PMT System**
- 2.2 Electronics
- 2.3 Calibration Systems
- 2.4 DAQ and Computing
- 2.5 Water Purification Systems
- 2.6 Slow control and monitoring
- 2.7 Installation and Integration

In terms of cost drivers we have an approximately even split in impact and where to put our efforts to get it right!

Cost estimating methodology

- Use as input data :
  - SuperK → UNO analysis
  - 2007 version of Multi-module proposal for Homestake
  - Updated information from recent projects or quotes as available

  Provide a lower base limit
- Consider Cavity and Instrumentation separately
  - Determine costs for 1, 2, and 3 modules
    - I.e. cost of 3 ≠ 3 x 1
- Apply :
  - Inflation (this could be a big deal!)
  - **EDIA (engineering, design and oversight through all project phases)**
  - **realistic manpower requirements for procurement, fabrication, installation, Project Management, QA/QC, ES&H….**
  - Contingency
- Perform an optimization analysis
- Study the non-cost driver systems

This is the part that is ALWAYS underestimated

Estimates in hep-ex/0608023v2 12 Jan 2007

6.1 Photomultipliers

For this estimate we use a total photocathode coverage of 25% which implies ~50,000 PMTs per 100 kT module. The cost used in the total PMT estimate is scaled from the 20 cm tubes used in SNO and is not based on manufacturer's quotations. Nevertheless, all manufacturers have accepted, in principle, that the estimate of $800 per PMT is not unrealistic. To this $800 number we add an additional 10% for the PMT testing costs plus the cost of the base and the waterproofing that surrounds the base.

$880/pmt

6.2 Mechanical Structure

The individual PMTs must be fixed in well known locations evenly distributed across the interior surface of the 50 m by 50 m cavity. To do this, a mechanical structure must be designed and installed. There are a number of suggested schemes for achieving this mounting, but not yet any engineered plan. Therefore we estimate this system cost on general grounds. The SNO mechanical mounting was for a spherical surface, much more complex than the simple cylinder of this detector, and therefore not a good cost model. The SK scheme is plausible for this case, but we do not have access to their cost data. Including installation labor, a simple model gives about $165 per PMT total cost for the structure.

$165/pmt

6.3 Electronics and DAQ

The basic SNO electronics system has performed nicely and that architecture should work well for the detector proposed here. However, the custom integrated circuits were manufactured in processes that are no longer available and many of the commercial parts are obsolete or obsolescent so a redesign in detail will be necessary. This will also present an opportunity to remove some of the minor flaws of the SNO implementation.

The SNO production and development costs are well documented and we have scaled for inflation to arrive at a per PMT cost of about $120 for front end electronics; trigger system; low voltage power; and high voltage power. The development costs are taken as the same number of people-years required for the original SNO system plus silicon chip and printed circuit prototyping costs.

The DAQ system involves largely development, but there is a small cost for the computers needed for data recording; on line monitoring, for slow controls (largely environmental controls); and miscellaneous networking and GPS interfaces. These add a fixed cost per module of about $75k. The DAQ development costs are assumed similar to SNO's at about five people-years.

$120/pmt

6.4 PMT Cables and Connectors

The cable running from each PMT to the electronics, presumably located around the periphery of the module above the water surface, is a significant cost item. For a 50 m diameter x 50 m high detector and equal length cables to allow an isochronous trigger, each cable needs to be at least 70 m long. High quality waterproof transmission line similar to that used in SNO costs about $0.50 per meter to which one must add the assembly and testing costs and the connectors.

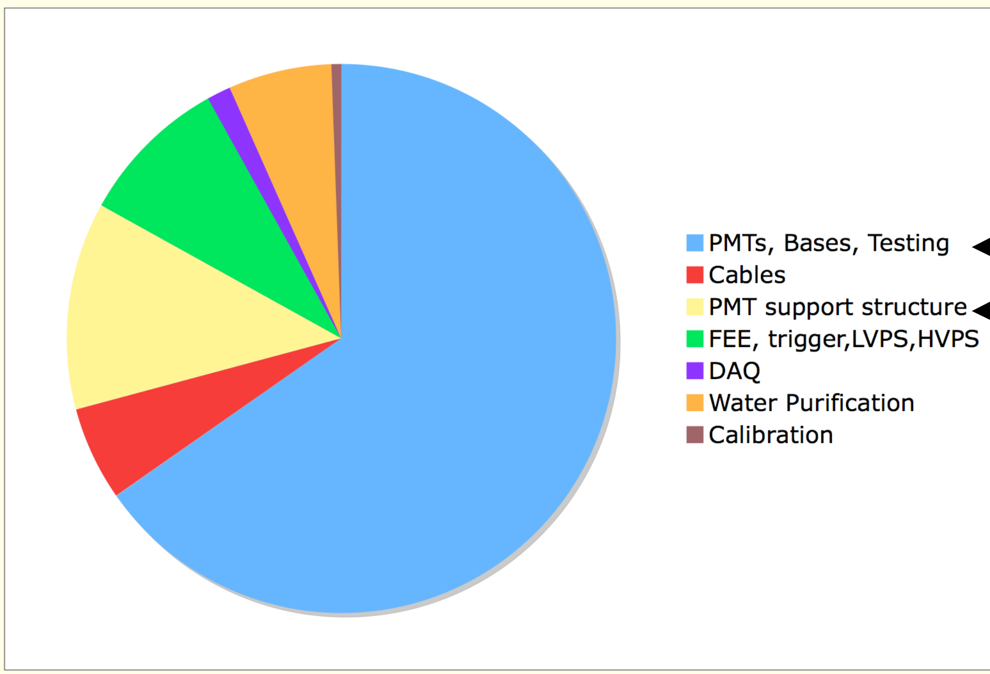
It is possible to imagine for the right circular cylinder geometry of a module that it would be possible to eliminate a *wet end* connector and simply pot the cable and base as a unit. For conservatism, and because there are unknown installation costs associated with pre- attached cables, we have assumed a *wet end* connector with full waterproofing for a total assembled cable cost of about $77.

$77/pmt

Estimate for 100kT using hep-ex/0608023v2 12 Jan 2007 (same as slide 20)

One 100kT module

	FY07 ($)		$ for 50,000 PMT
PMTs, Bases, Testing	880	per pmt	44,000,000
Cables	77	per pmt	3,850,000
PMT support structure	165	per pmt	8,250,000
FEE, trigger,LVPS,HVPS	120	per pmt	6,000,000
DAQ	1,075,000	per detector	1,075,000
Installation	8,750,000	perdetector	8,750,000
Water Purification	4,500,000	per detector	4,500,000
Calibration	400,000	per detector	400,000

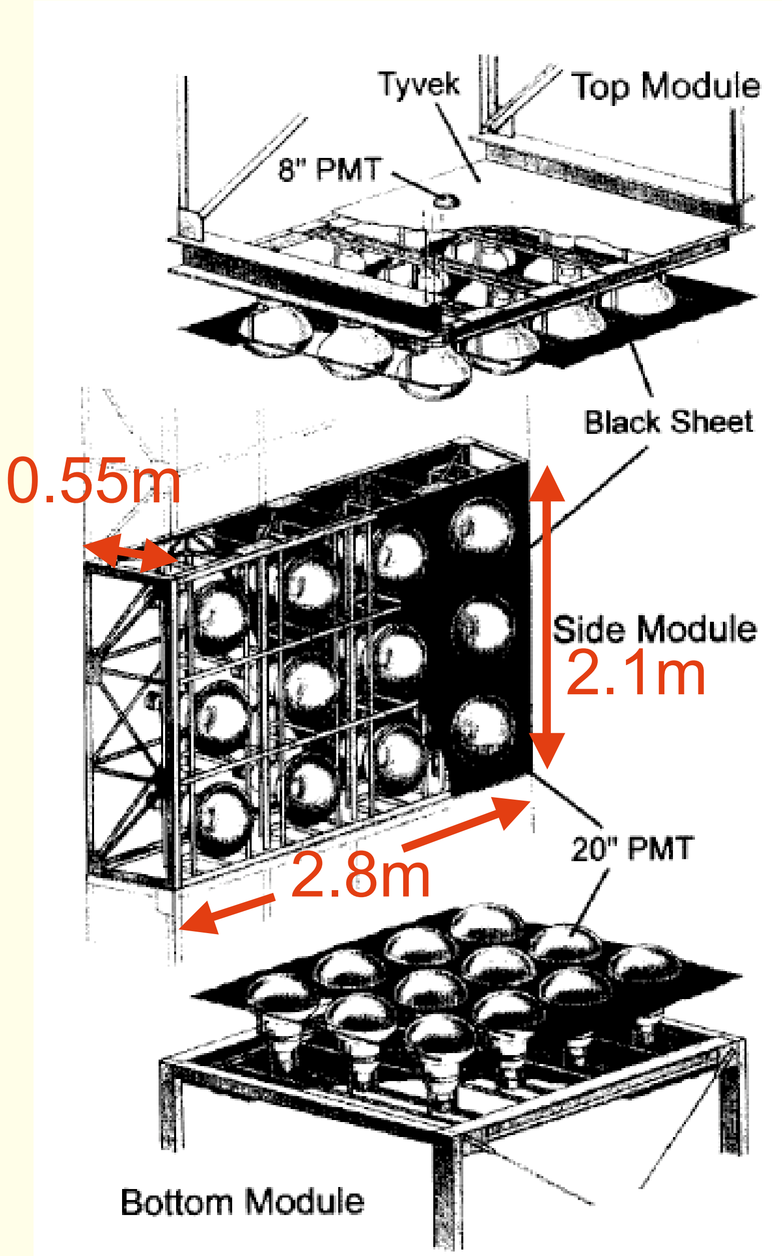


$77 M
(in FY07, no contingency)

Cost driver : we need to get this right

Is this realistic?
We need a design…

Super-K PMT Support Structure



146 Top modules
146 Bottom modules } 11,146 20” PMTs
638 Side modules

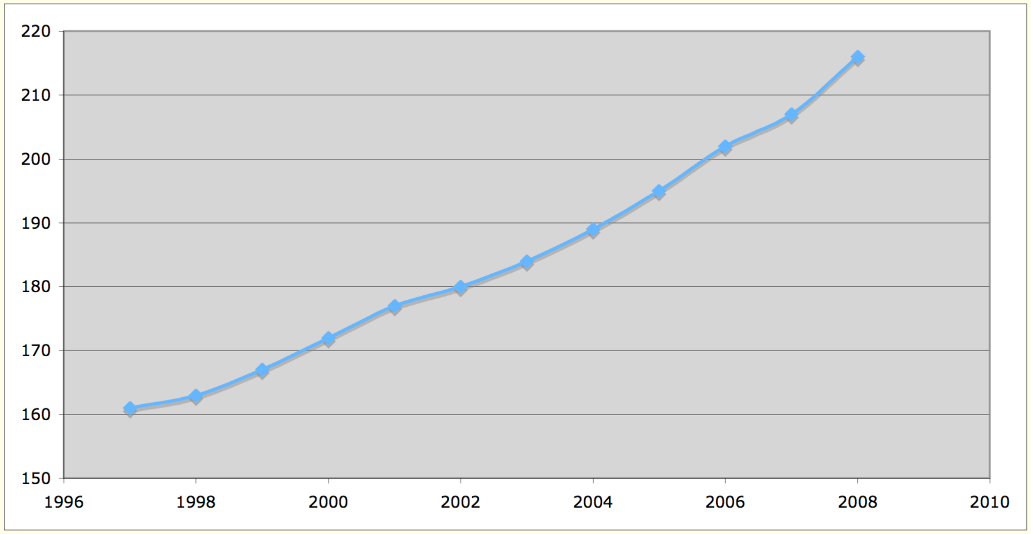
930 modules

Cost in 1996 : $4.58M → $411/PMT

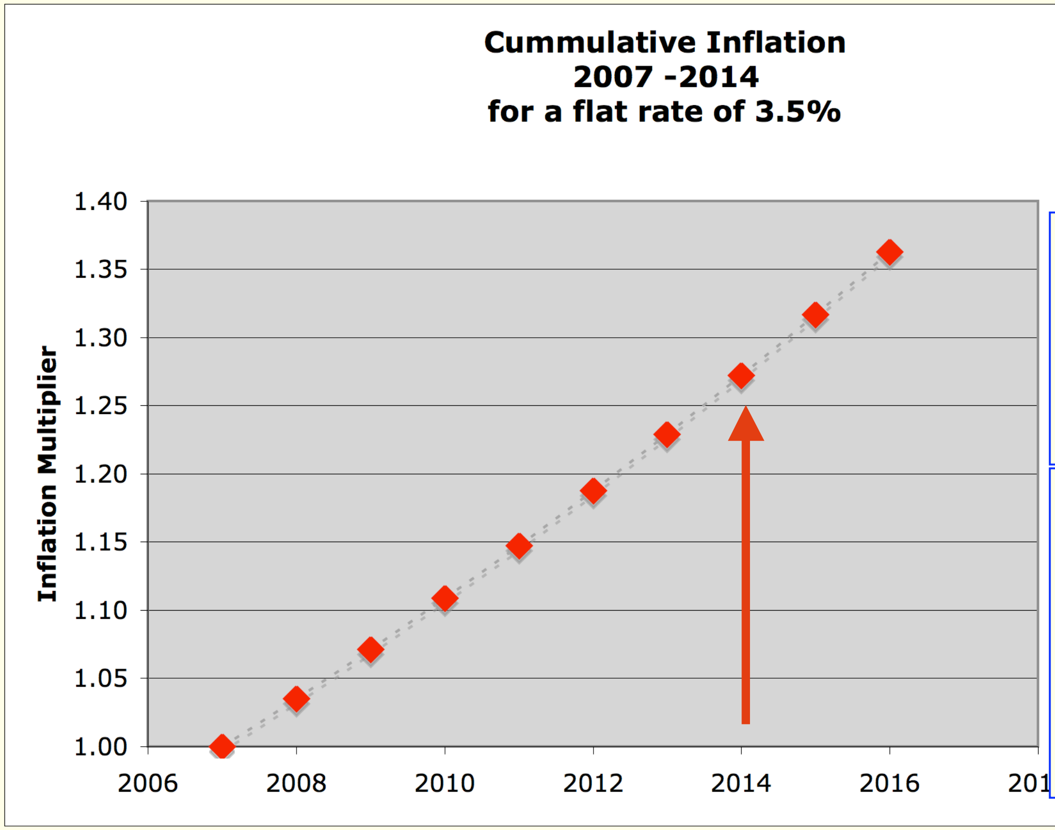
We will need ~5 x more, but smaller PMTs; We need to cover a factor of ~2.3 larger surface area.

We need a conceptual design so that we can estimate a cost.

It’s the economy, stupid!



Input data for inflation calculations : CPI (1997- 2008) *(Note - these do not appear to be very valid for the construction industry - see backup slides)*



If inflation continues at the current rate, by the time we get to start we pay a 25% increase just from inflation

It's also possible that we soon enter a period of economic de-flation! We probably shouldn't count on it; and should request guidance from the funding agencies

PMT Cost Estimate

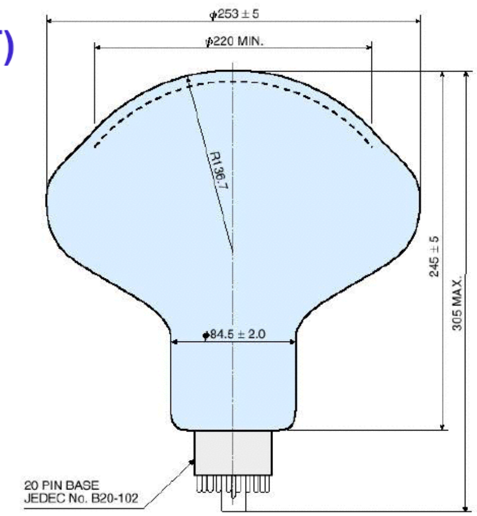
PHOTOMULTIPLIER TUBES Contract

THE UNIVERSITY of WISCONSIN MADISON

BUSINESS SERVICES
PURCHASING SERVICES

R7081 (10 inch)
R7081-20 (14-ST)

Fits for 13 inch Glass Sphere

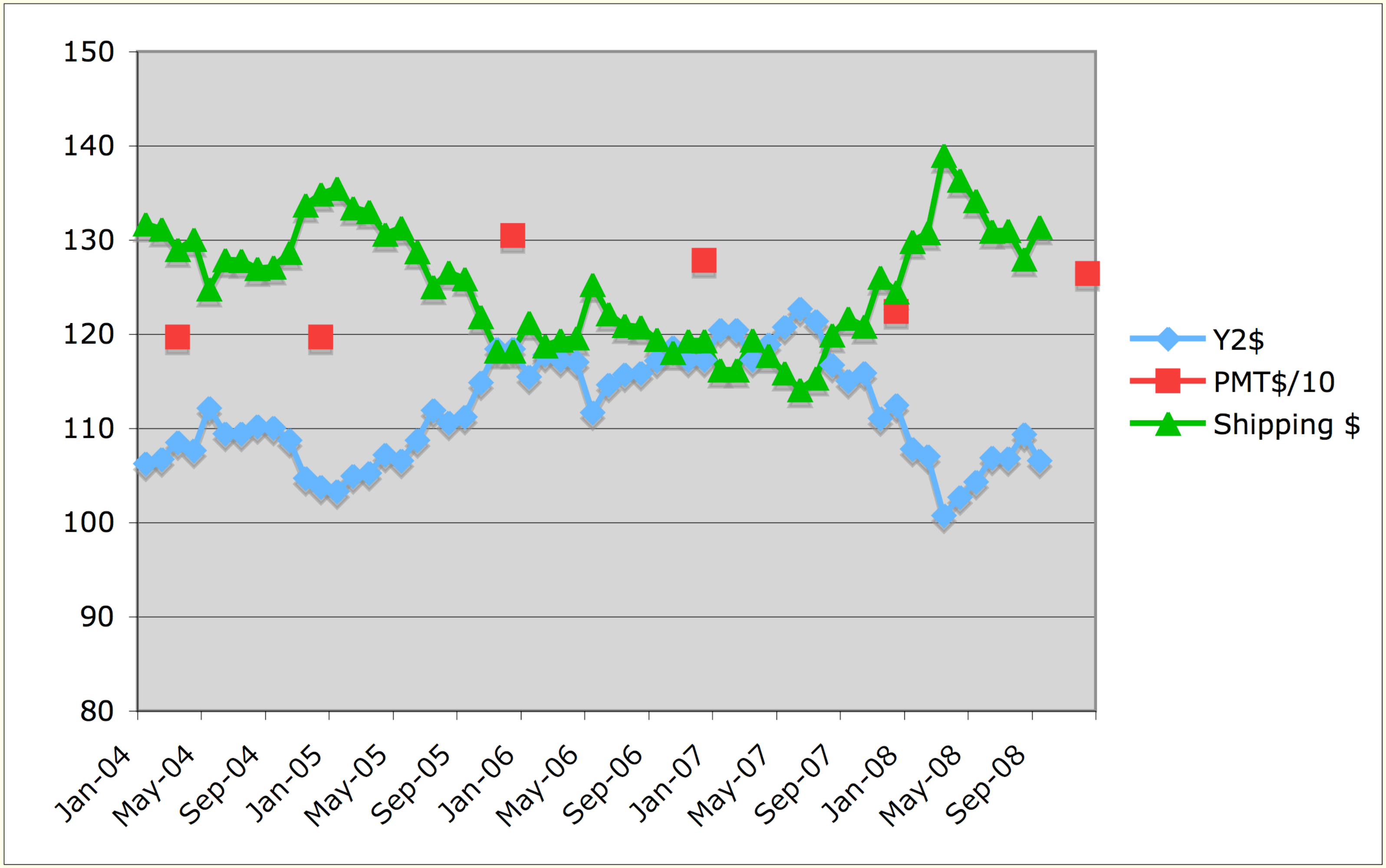


PHOTOMULTIPLIER TUBES

(contract last updated 02/22/2008)

SCOPE: The IceCube project is a collaborative effort involving US and the International institutions. The project will require approximately 5136 photomultiplier tubes over the course of this contract. It is anticipated that the University will purchase approximately 3500 photomultiplier tubes, and other collaborators will purchase the remaining tubes.

Ice Cube PMTs



~$1250/PMT + shipping (determined at time of shipping)
$142 for base (materials, assembly and testing)

From M. Diwan Nov. 2007

PMTs

	Cost for one
28 cm dia PMT	$933
Installation/PM	$175
Electronics/PM	$127
Cable/PM	$86
Total per PMT	$1317

50000 PMTs per 100 kT tank => 25% coverage
Sanity checks: Auger PMT cost $629/each for 5000 units with 9 inch diameter. Base cost additional $175. Other costs have basis with SNO actual costs with adjustments for differences.

We need to update these #'s and do a real "Basis of Estimate"

Cost Summary for Detector Instrumentation

Work in progress

Some Question(s) of Optimization (and other design considerations and choices)

- Need to evaluate the pros and cons as well as cost and schedule implications of the modular concept
  - i.e. 3x100, 2x150, 1x300 ?
- Need to justify the choice of photocathode coverage, and evaluate the cost implication if that choice changes (increases) as the design advances
  - 15, 20, 25,40% ?
- Need to demonstrate that the choice of PMT (size and efficiency) meets the need of the experiment and what are the implications if that choice changes
  - 8, 10, 20" dia ?
- We need to understand what trade offs can be made to maintain costs, as the design evolves (i.e. as real costs and cost drivers become known)
- We need to carefully look at the systems that don't look like cost drivers and make sure they can stay that way
  - Lots of little systems can add up to 25 - 50% of the TPC

Why do we need to answer all of these questions if we already know the answers?

- Whether we get to do this project or not is all about the cost…
- If we don't ask and answer the obvious questions pro-actively, we will certainly be asked them by reviewers, and we'll have to scramble to document the answers.
  - *Been there, done that and don't want to do it again!*
- We need *pretty* good answers to these and many more by CD-1, and final answers and decisions by CD-2

	WC-100	WC-150	WC-300	WC-100	WC-150	WC-300	WC-100	WC-150	WC-300
Photo cathode coverage	**0.2**	**0.2**	**0.2**	**0.25**	**0.25**	**0.25**	**0.3**	**0.3**	**0.3**
PMT diameter	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
no. of modules	**3.00**	**2.00**	**1.00**	**3.00**	**2.00**	**1.00**	**3.00**	**2.00**	**1.00**
pi	3.14159	3.14159	3.14159	3.14159	3.14159	3.14159	3.14159	3.14159	3.14159
Cavity diameter	54.5	60	68	55	60	68	55	60	68
Cavity height (or length)	55	67	100	55	67	100	55	67	100
Cavity Volume	128305	189438	363168	130671	189438	363168	130671	189438	363168
Concrete liner thickness	1	1	1	1	[illegible]	[illegible]	1	1	1
Water Volume	119061	177019	342119	121340	[illegible]	[illegible]	121340	177019	342119
Liner volume	9244	12419	21049	9331	[illegible]	[illegible]	9331	12419	21049
upper veto	2	2	2	2	[illegible]	[illegible]	2	2	2
lower veto	2	2	2	[illegible]	[illegible]	[illegible]	2	2	2
side wall space	0.2	0.2	0.2	[illegible]	[illegible]	0.2	0.2	0.2	0.2
Outer Volume	11071	13677	18616	[illegible]	[illegible]	18616	11259	13677	18616
wall support thickness	0.42	0.42	[illegible]	[illegible]	[illegible]	0.42	0.42	0.42	0.42
Active diameter	53.26	[illegible]	[illegible]	[illegible]	58.76	66.76	53.76	58.76	66.76
Active height	51	[illegible]	[illegible]	[illegible]	63	96	51	63	96
Active Volume	113622	[illegible]	[illegible]	115765	170842	336042	115765	170842	336042
AV/TV	0.89	[illegible]	[illegible]	0.89	0.90	0.93	0.89	0.90	0.93
Active Surface Area	12989	17053	27135	13153	17053	27135	13153	17053	27135
PMT area	0.049087344	[illegible]	[illegible]	0.049087344	0.049087344	0.049087344	0.04908734	0.04908734	0.04908734
Number of PMTs per module	**52923**	[illegible]	**110559**	**66989**	**86852**	**138199**	**80387**	**104222**	**165838**
#PMTs Total	**158768**	**138963**	**110559**	**200968**	**173704**	**138199**	**241161**	**208445**	**165838**
Top Vertex Cut	1	1	1	1	1	1	1	1	1
Bottom Vertex Cut	1	1	1	1	1	1	1	1	1
Side Vertex Cut	1.1	1	1	1	1	1	1	1	1
Fiducual Volume per module	**100334**	**154349**	**309621**	**103104**	**154349**	**309621**	**103104**	**154349**	**309621**
FV/TV	0.78	0.81	0.85	0.79	0.81	0.85	0.79	0.81	0.85

Example continued

Choose your favorite numbers for the cost drivers :
$\$500/m^3$ excavation; \$1400/channel for instrumentation
This exercise ignores small systems and has no contingency.

10" PMT	20%			25%			30% coverage		
	WC-100	WC-150	WC-300	WC-100	WC-150	WC-300	WC-100	WC-150	WC-300
Cavity cost per module	64,152,740	94,718,939	181,583,902	64,152,740	94,718,939	181,583,902	64,152,740	94,718,939	181,583,902
PMT cost per module	74,091,562	97,274,218	154,782,366	92,614,453	121,592,773	193,477,957	111,137,344	145,911,328	232,173,549
Cost per module	138,244,303	191,993,157	336,366,268	156,767,194	216,311,712	375,061,859	175,290,084	240,630,266	413,757,451
# of modules	3	2	1	3	2	1	3	2	1
Sum of Cavity excavation	192,458,221	189,437,877	181,583,902	192,458,221	189,437,877	181,583,902	192,458,221	189,437,877	181,583,902
Sum of Instrumentation for 300kT	222,274,687	194,548,437	154,782,366	277,843,359	243,185,546	193,477,957	333,412,031	291,822,655	232,173,549
Cost per KT to Instrument	740,916	648,495	515,941	926,145	810,618	644,927	1,111,373	972,742	773,912
Total of Cost Drivers	414,732,909	383,986,314	336,366,268	470,301,581	432,623,423	375,061,859	525,870,252	481,260,532	413,757,451
Total Cost/kT	1,382,443	1,279,954	1,121,221	1,567,672	1,442,078	1,250,206	1,752,901	1,604,202	1,379,192

We next need to complete the following tables:

WBS 1.0	1 time costs	1st module	2nd module	3rd module
Access tunnels				
Occupiable Underground space				
Chamber excavation				
Chamber liner				
Infrastructure				
Design (EDIA)				
Contingency				
Inflation				
Total				

WBS 2.0	1 time costs	1st module	2nd module	3rd module
PMT system				
DAQ and Slow Control				
Calibration				
Water Purification				
Environmental Control				
Underground facilities				
Surface facilities				
Design (EDIA)				
Contingency				
Inflation				
Total				

This is the level of costing needed for CD-0. It needs to be done accurately enough that we know that we can deliver the Project for the upper limit that we give which includes contingency.

Next Steps

- Cavity
  - Do geotechnical investigation
  - Refine/update unit costs, including rock disposal
  - Develop costs for the infrastructure requirements
- Instrumentation
  - Develop an acquisition model
    - This will help us determine who does what, and therefore we can start to get a handle on SWF costs (they are always a killer!)
  - Develop a conceptual design for the PMT support structure
  - Put conceptual design effort into the smaller(?) systems : calibration, water purification…
- Simulation
  - Understand the acceptable range of PMT coverage
  - Optimize the FV vertex cut
  - Do we need an outer veto region?

Plus many more that I’m sure I’ve forgotten!

Backup Material

Cost data for cavity construction

From UNO proposal

Table 2. Estimated Unit Costs: The excavation cost is assuming a horizontal access tunnel and rock quality (Q value) of 100. The PMT unit cost including cable cost is based on a 50k PMT order. It is $2,850 if 100k PMTs are ordered. A conversion rate of 1$ = 100 yen is used.

Item	Unit Cost	Source
Excavation	$\$260/m^3$	L. Petersen
20″ PMTs	$3,100	Hamamatsu
8″ PMTs	$1,200	Hamamatsu
Electronics	$170/channel	
Water Tank	$\$2,076/m^2$	

MINOS Cavern at Soudan

Rock Excavation only :

- 1994 Proposal estimate : $3.3M
- FY2000 actual : $7M for 11,500 m^3
- Escalate to FY08 → $780/ m^3

Includes all EDIA, OH&P, excavation, access ways, and basic finishing (not outfitting).

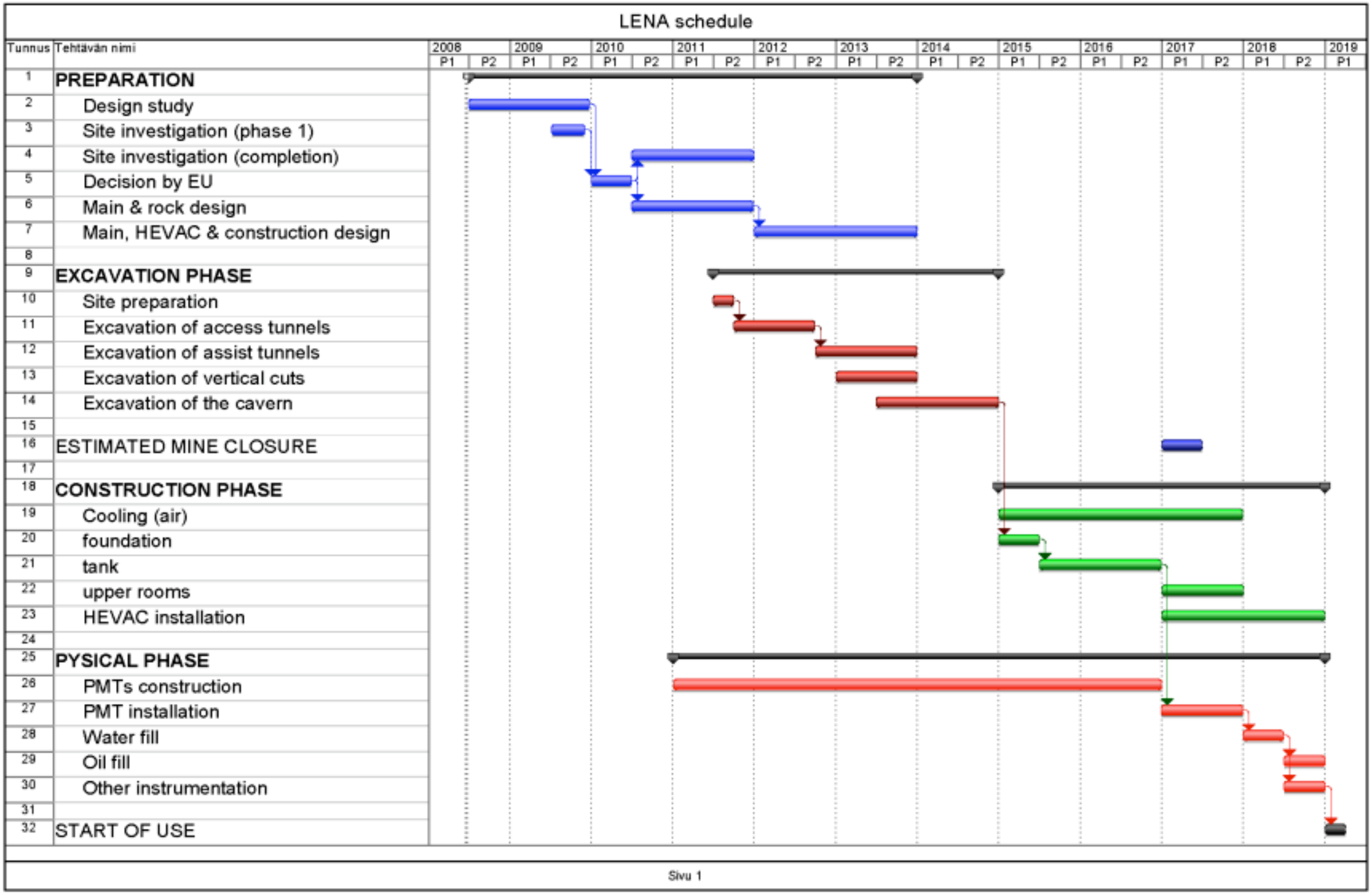
Independent example from Europe

Total costs / cash flow

The total costs, as calculated, are not including any value added taxes. As LENA is to be a European installation, the construction is tax free for all, who contribute. The total costs are:

1) Laboratory costs			75 M€
	Excavation costs, total	47 M€	
	Site investigations + surface infrastructure	6 M€	
	HEVAC costs, total	22 M€	
2) Detector costs			222 M€
	Construction costs, total	37 M€	
	Liquid handling	10 M€	
	PMT’s (including electronics)	75 M€	
	Liquid scintillator (50 kT)	100 M€	
3) Design & consulting costs			30 M€
Reservations (risks, unforeseen 25%)			82 M€
Total (0% VAT)			**409 M€**

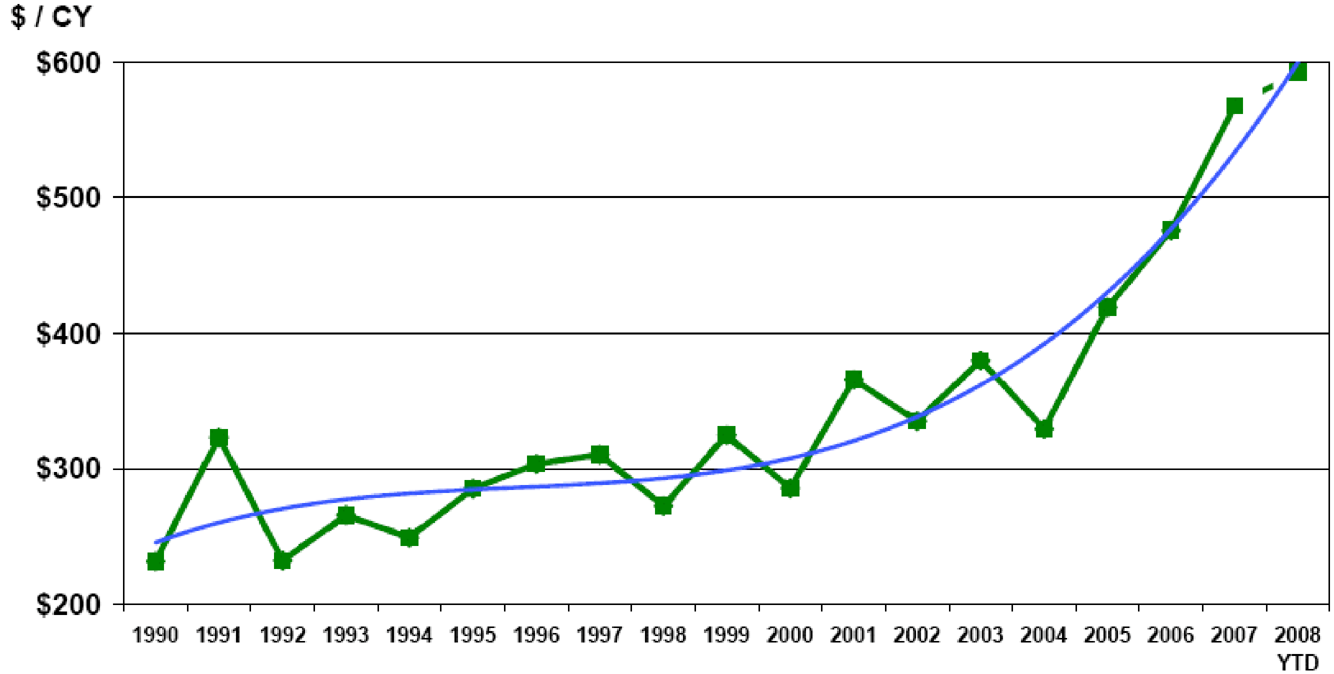
2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	total
< 1	< 2	6	29	37	45	45	67	67	74	36	**409M€**


LENA schedule
Tunnus
Tehtävän nimi
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
P1
P2
1 PREPARATION
2 Design study
3 Site investigation (phase 1)
4 Site investigation (completion)
5 Decision by EU
6 Main & rock design
7 Main, HEVAC & construction design
8
9 EXCAVATION PHASE
10 Site preparation
11 Excavation of access tunnels
12 Excavation of assist tunnels
13 Excavation of vertical cuts
14 Excavation of the cavern
15
16 ESTIMATED MINE CLOSURE
17
18 CONSTRUCTION PHASE
19 Cooling (air)
20 foundation
21 tank
22 upper rooms
23 HEVAC installation
24
25 PYSICAL PHASE
26 PMTs construction
27 PMT installation
28 Water fill
29 Oil fill
30 Other instrumentation
31
32 START OF USE
Sivu 1

Construction Industry Escalation Data

STRUCTURAL CONCRETE

UNIT BID PRICE



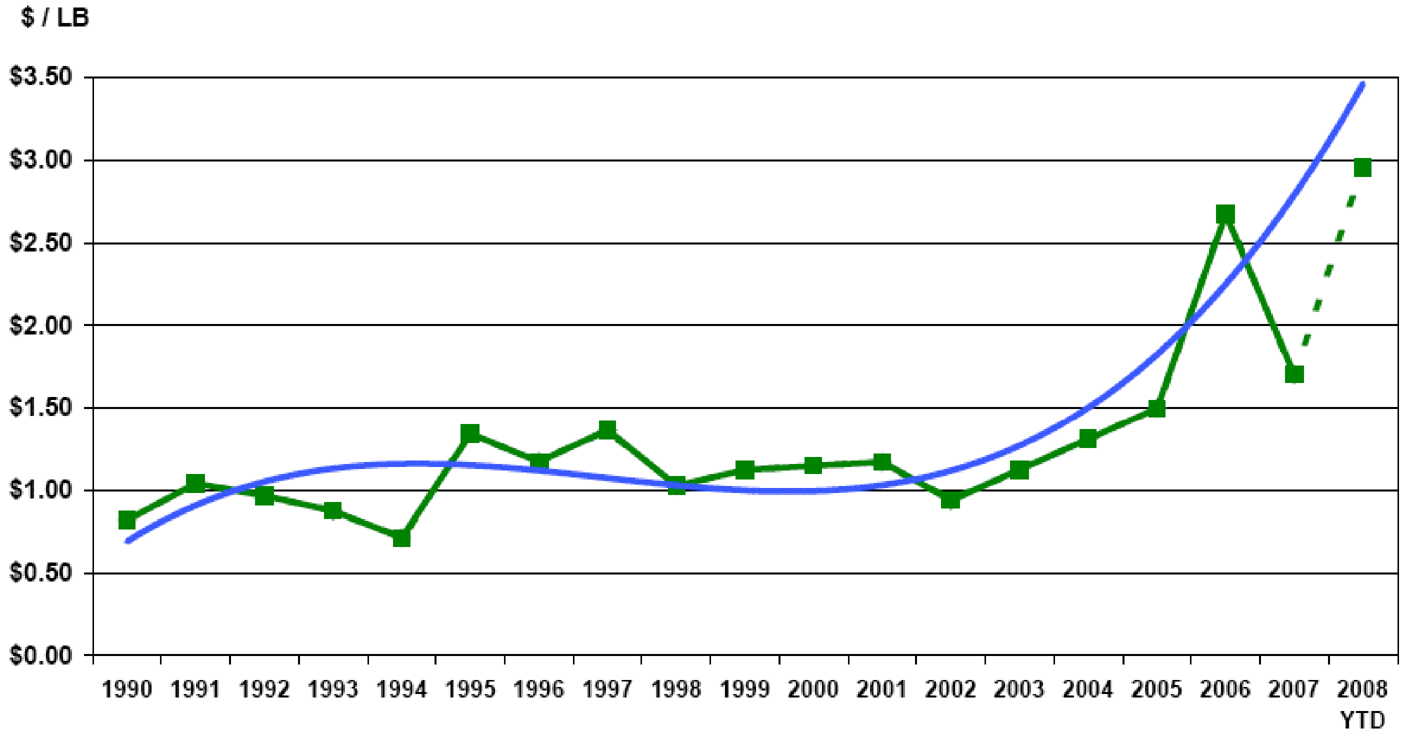
Washington State Department of Transportation

For more information, please call the WSDOT Construction Office at (360) 705-7822
or visit http://www.wsdot.wa.gov/biz/construction

7/2/2008

STRUCTURAL STEEL

UNIT BID PRICE



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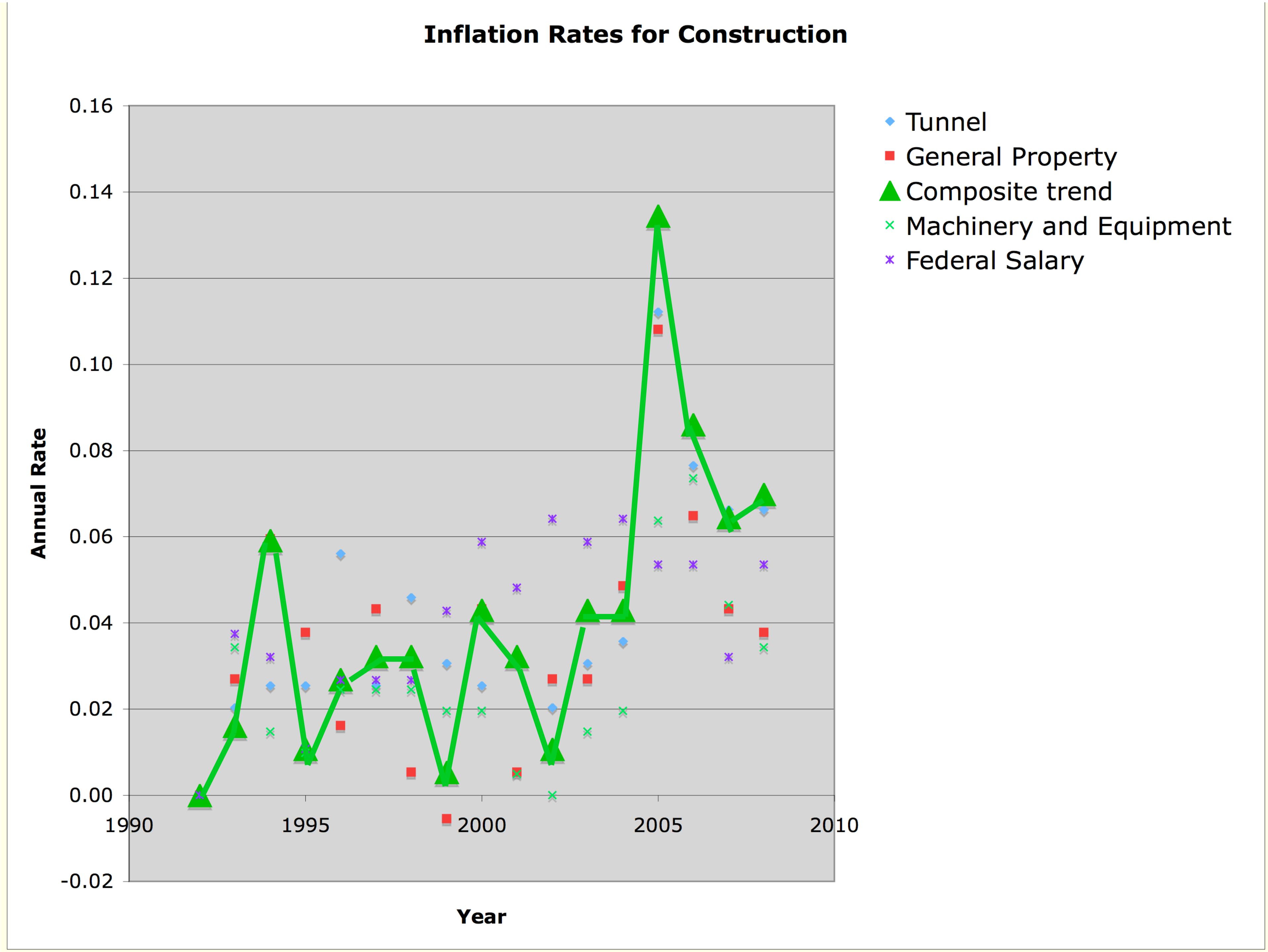

Inflation Rates for Construction
Annual Rate
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
1990
1995
2000
2005
2010
Year
Tunnel
General Property
Composite trend
Machinery and Equipment
Federal Salary

Yen vs. US$ exchange rates

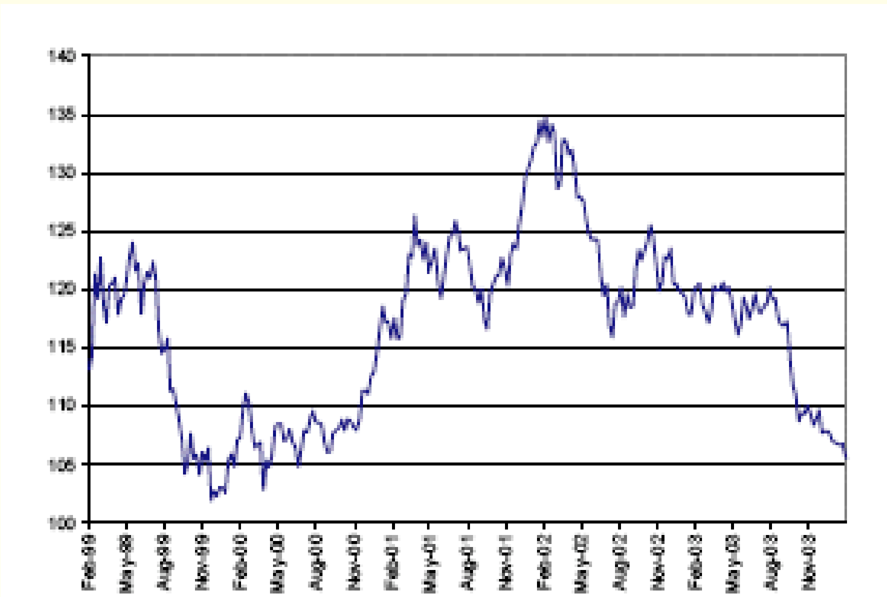

Figure 1. Yen/Dollar Exchange Rate