Cost Estimating for Cavities & Cryomodules – Info needed from contracts for these industrial studies

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similar to presentation at Paris EC Meeting, July 2010

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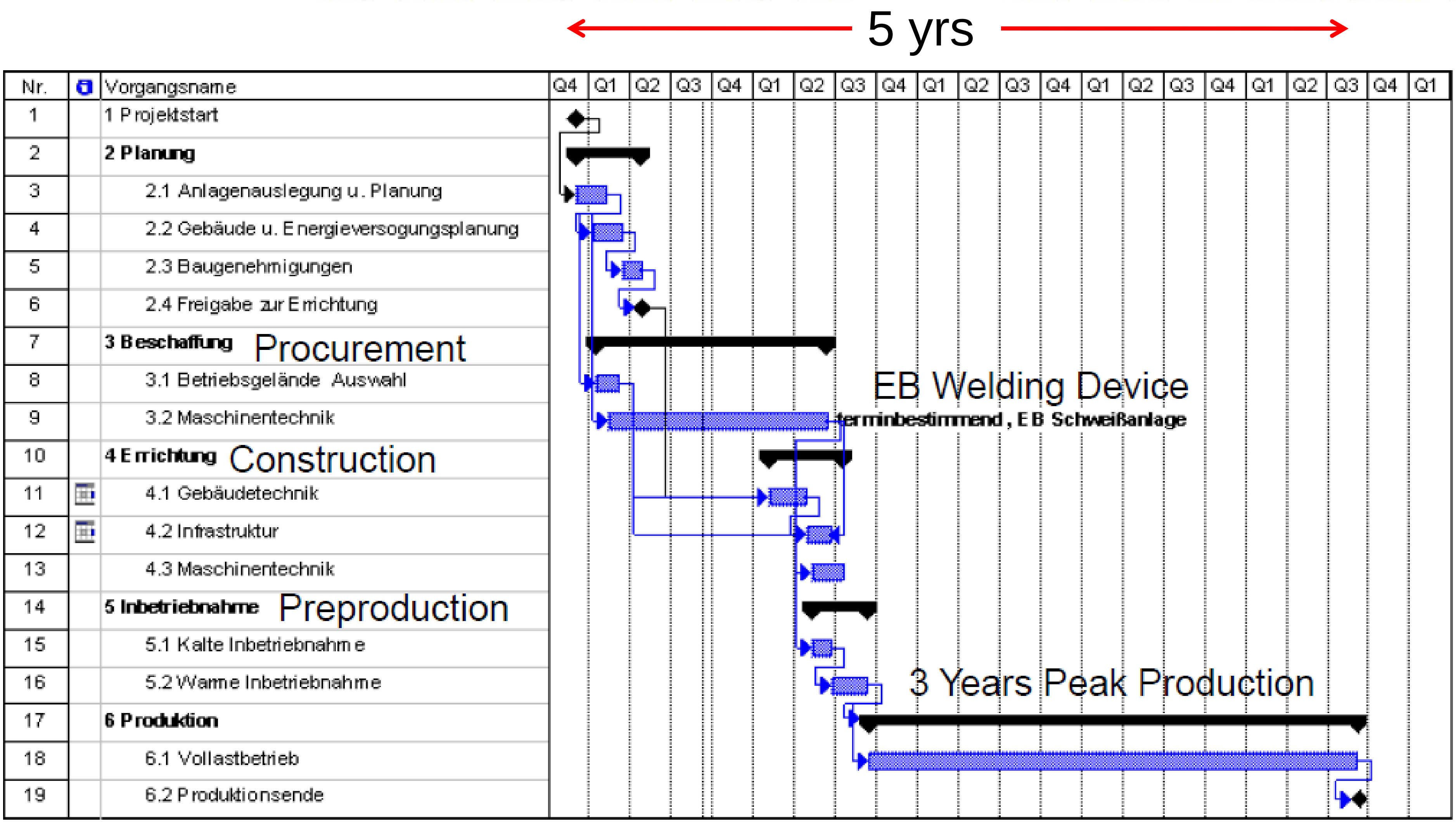
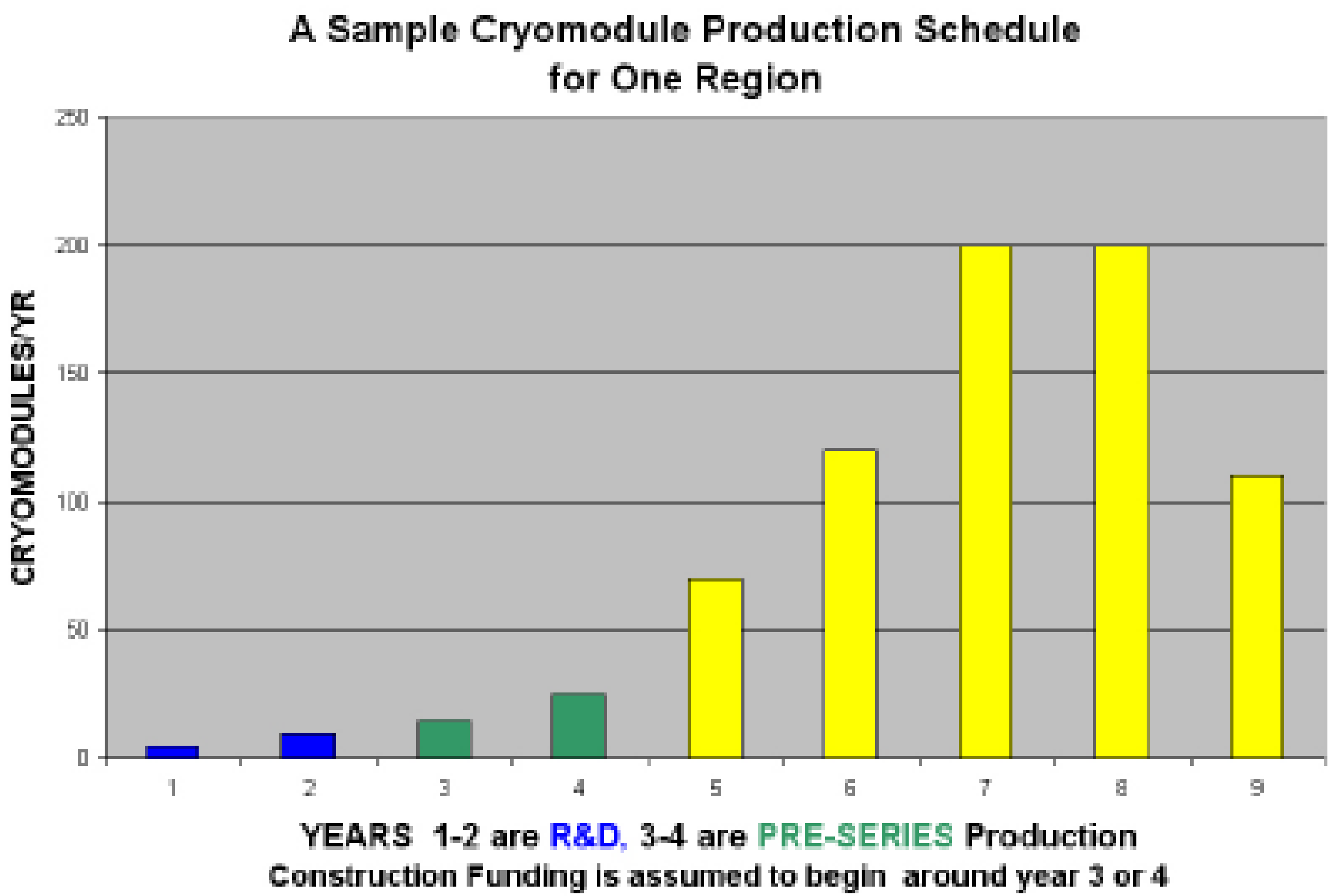
what are the issues?

- What is the cost? But that depends on the production model
- How do you minimize cost vs. risk vs. production rate?
- Is a 5 year production period realistic? How can we realistically qualify enough vendors and undertake a pre-series production run within funding and timescale?
- How does cost of ~ 18,000 cavities depend on # vendors?
- How do Learning Curves *L.C.* s apply?
- How do infrastructure, raw materials, purchased parts, touch-labor, quality assurance, management, profit factor, and administration factor into cost to be paid by ILC?
- How do we define cost estimate under the assumption of a three-region, in-kind contribution model?

TESLA Cavity Production Schedule



ILC RDR



A Sample Cryomodule Production Schedule
for One Region
CRYOMODULES/YR
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
YEARS 1-2 are R&D, 3-4 are PRE-SERIES Production
Construction Funding is assumed to begin around year 3 or 4

my thoughts, Akira's thoughts

- Need so much infrastructure and so many
  production lines to meet production rate
  => a ***major driving term*** – is RDR too optimistic?
- What are economies of scale for larger purchase of infrastructure, size of plant, management, admin?
- Are the Learning Curves for parallel production lines in the same plant independent, or do they benefit from common shared experience?
- What if you saturate # qualified vendors?
  => loss of free-market competition
- and always, "When do learning curves saturate?"

What was in RDR estimate?

- See Wilhelm Bialowons – Orsay Review – May 2007
- Based on TESLA Industrial Studies (most mature):
  - ***not*** based on Asia or Americas' R&D estimates
  - technical basis is TTF-FLASH experience
  - assumed a ***single vendor*** model.
  - Zanon: production of 2500 cryostats 8-cavites ea
  - Noell: 20,000 cavities w BCP & CM assembly
    - detailed WBS, time-motion, optimized plant
  - Thompson-Thales studied RF power couplers

Re-evaluated 250 CM for XFEL Supplement 2001

- relative values of TESLA & XFEL estimates were
  - ***consistent with*** a Learning Curve of ***87%***

RDR estimate (continued)

- XFEL TDR (2006) => in-house estimate for
  electro-polishing (no cost difference)
  plus increased steel and copper costs
- This led to ILC RDR estimate (2006) including
  escalation to 2007 & scaling to quantities
- After much debate and non-convergence,
  we assumed cavity Yield ($\geq$ 35 MV/m) = 80%
  but no reprocessing (throw-away if fail 1st test)
  => cavity cost factor = total paid/# good = 1/Y
  also assumed G(CM) ≥ 90% G(vertical test)
  – no losses between vert test => CM

so is there a problem here?

- XFEL experience for cavity fabrication tenders: ***more expensive w/o performance guarantee***
  XFEL had to assume the performance risk!
  Why are the tenders different from expectations?
  How do they impact/improve ILC TDR estimates?
- cavities are ***~X%*** of RDR estimate, so if cavity cost increases by factor ***f***, (what's included?)
  ILC estimate increases by ***~ f * X%***
- RDR model and estimate doesn't take into account multiple vendors over multiple regions to reduce production risk or to allow development of this SCRF technology in all regions

what information will we be getting?

- Cavity yield experience with electro-polishing: from ILC TDP R&D (cavity performance DB) – ***not enuf statistics quickly enuf*** for TDR est and from European XFEL – RI/ACCEL half will have final electro-polish – ***too late*** for TDR important for overall cost and whether allowing spread of cavity operating gradients is economic
- Experience and guidance from Asian pilot plant for cavities at KEK with industrial participants
- Industrial Studies from Asian (and US) vendors being discussed here today!

what do we need for TDR estimate?

Not only a more realistic cost estimate for production in all three global regions!

We also need guidance in optimizing:

 # vendors vs. risk vs. cost vs. production time vs. governance model vs. management

Are we willing to show a cost estimate for which production of 1/3 of components in one region is substantially higher than in the other regions? How does one weigh those "intangibles" listed above, along with political realities?

From whose experience can we get such guidance?

some quick indications from Learning Curves

- Remember: TESLA/XFEL industrial estimates were ***bottom-up*** estimates for which L.C. was calculated, rather than using L.C. to scale few costs to large quantity costs (***dangerous***)
- Wright Learning Curve: (average over integral)

  <cost(2N)> = *L.C.%* * <cost(N)>

  Babcock-Noell industrial study for Cryomodules

  <TESLA(2,500)>/<XFEL(250)> => *L.C.% = 87%*

  Northrop-Grumman RHIC magnets- *L.C.%* = 85%

  LHC Dipoles (3 vendors) - *L.C.% = 80-85%*

  (mutual cooperation after all LHC contracts let)

LHC dipole experience

Learning Percentage of Selected Reference Industries

Industry	ρ
Complex machine tools for new models	75%-85%
Repetitive electrical operations	75%-85%
LHC magnets	80%-85%
Shipbuilding	80%-85%
Aerospace	85%
Purchased Parts	85%-88%
Repetitive welding operations	90%
Repetitive electronics manufacturing	90%-95%
Repetitive machining or punch-press operations	90%-95%
Raw materials	93%-96%

extrapolating from the few to the many

Learning Curve Sensitivity PHG 1oct2010.xls

http://cost.jsc.nasa.gov/learn.html

Learning curves continue forever, do not "saturate"

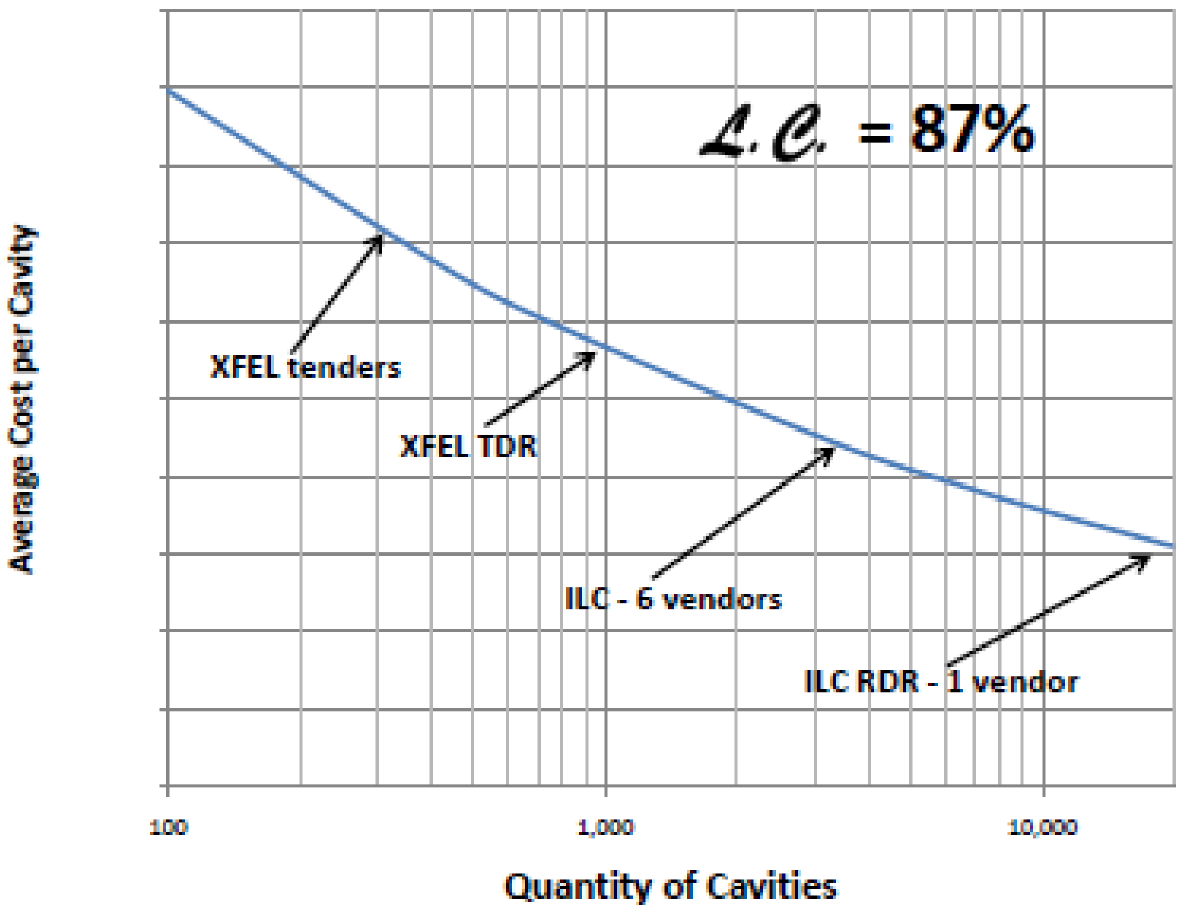
distrib. over # vendors

relative cost	LC = 85%	LC = 86%	LC = 87%	LC = 88%	LC = 89%
1*18K	0.72	0.85	1.00	1.18	1.38
2*9K	0.85	0.99	1.15	1.34	1.55
3*6K	0.93	1.09	1.25	1.44	1.66
6*3K	1.10	1.25	1.43	1.64	1.86

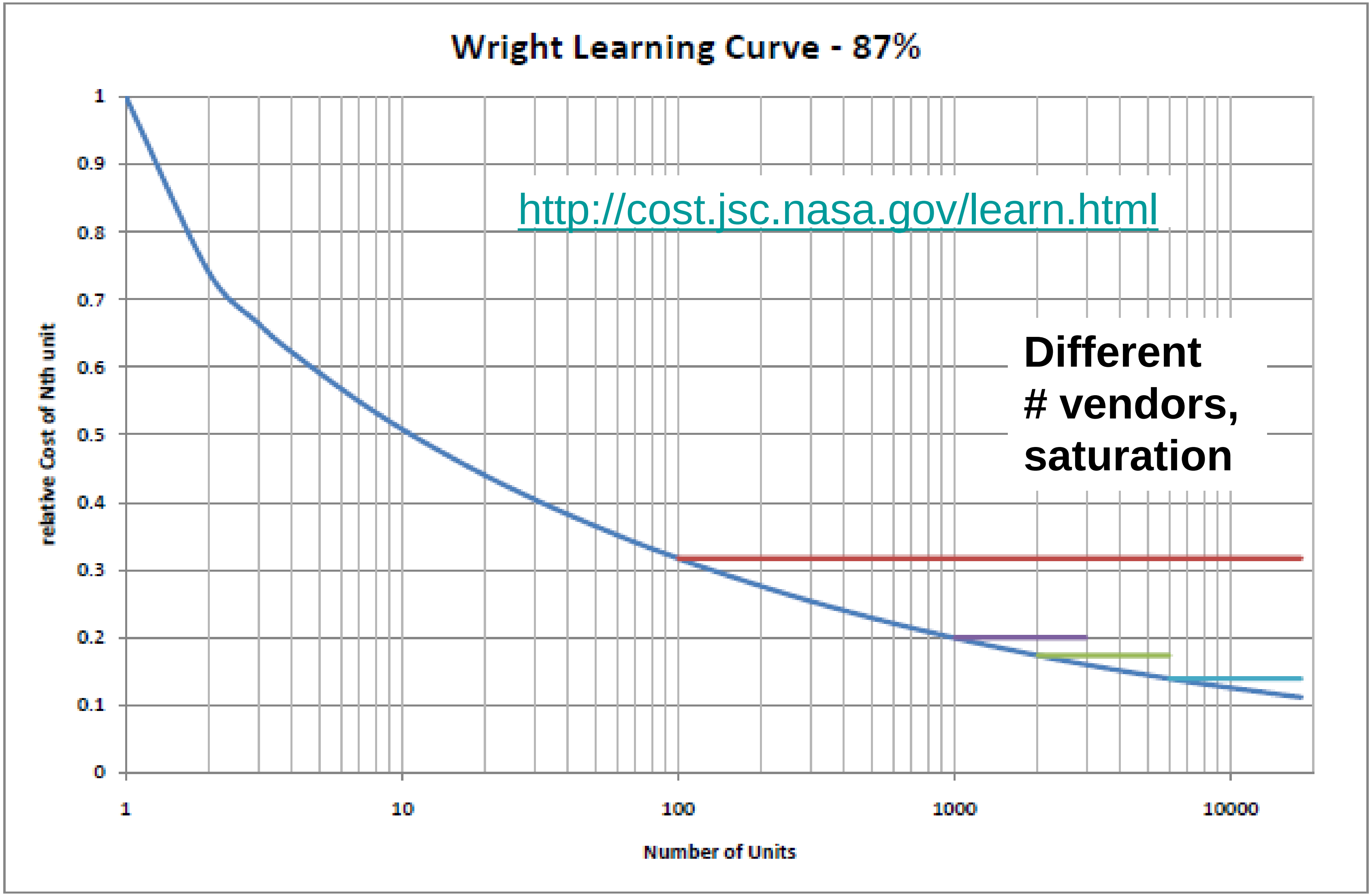
1*18K => 1.00 for RDR est

interpreting & projecting XFEL cavity bid

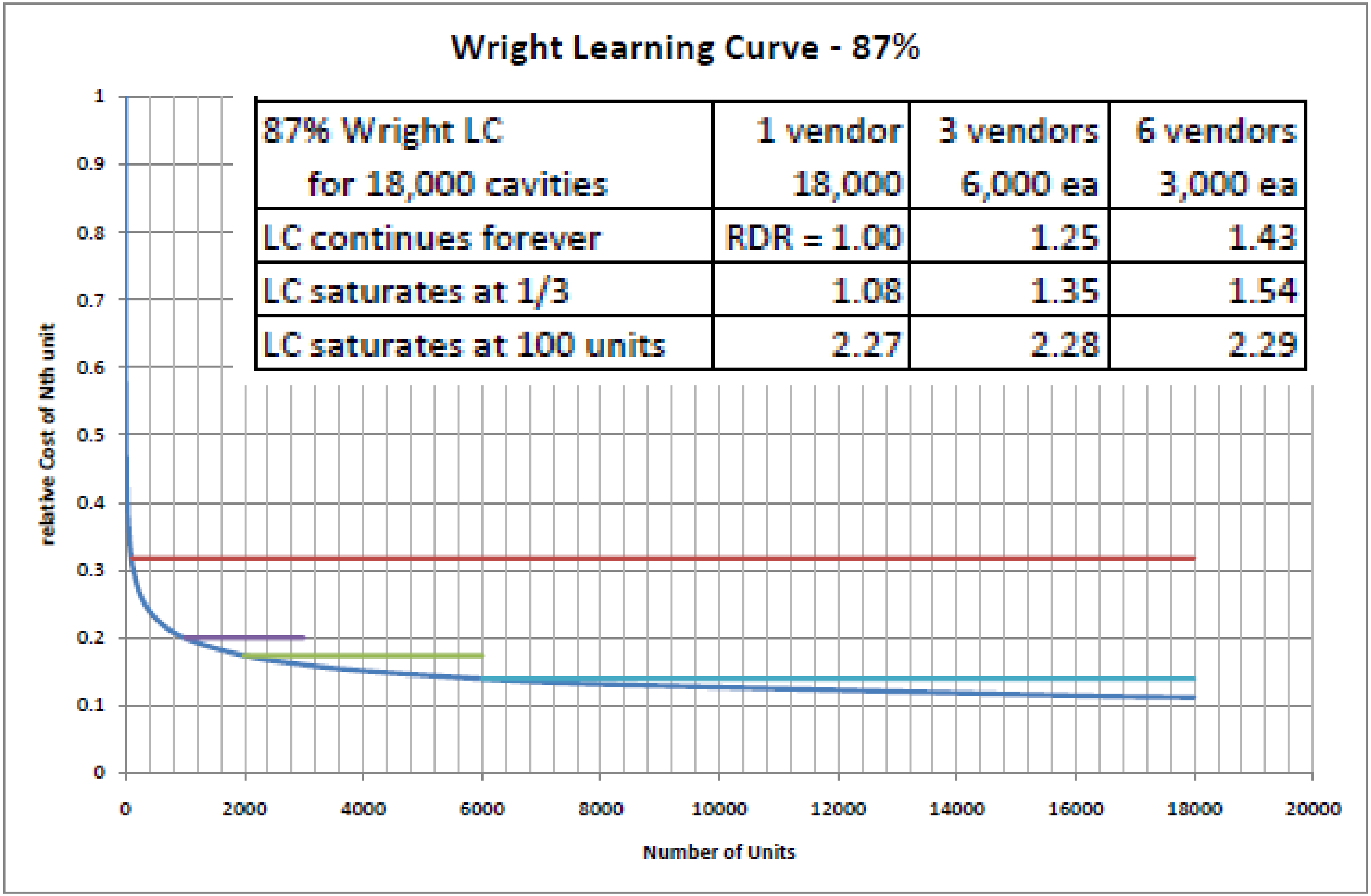
- Based on incomplete knowledge of XFEL bids, what's included in common, imperfect TESLA



Learning Curves ≤ 18K cavities (11% of RDR)

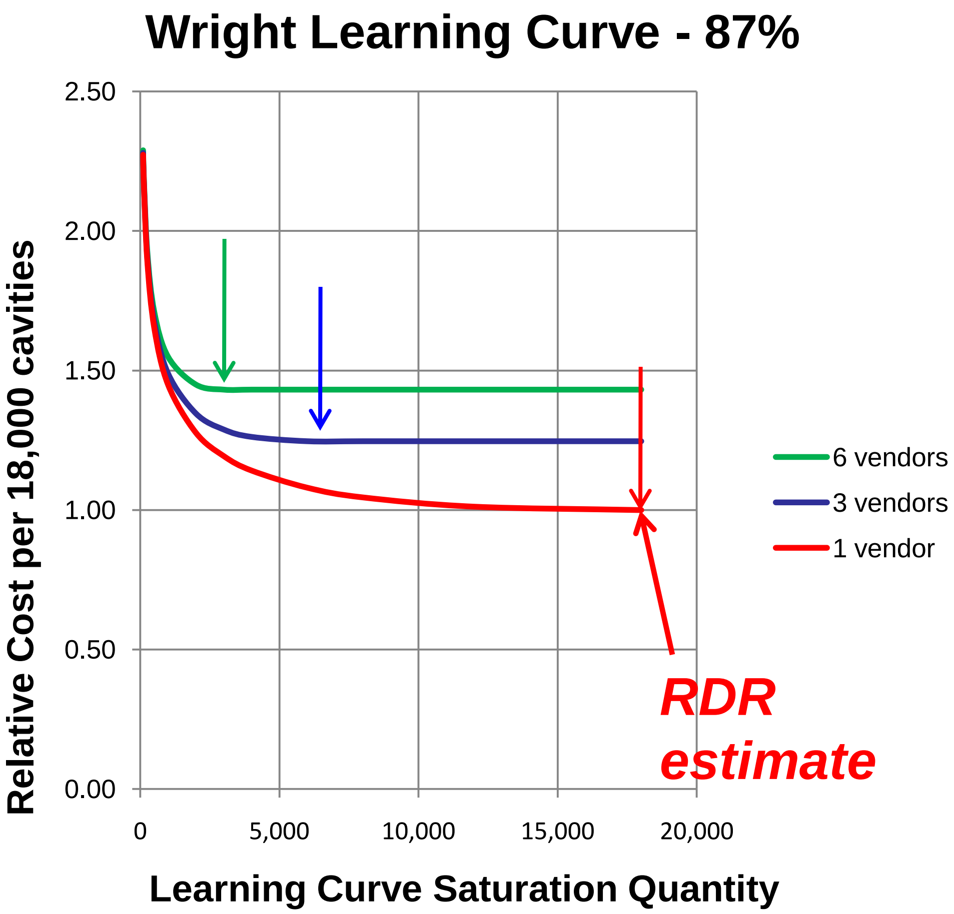


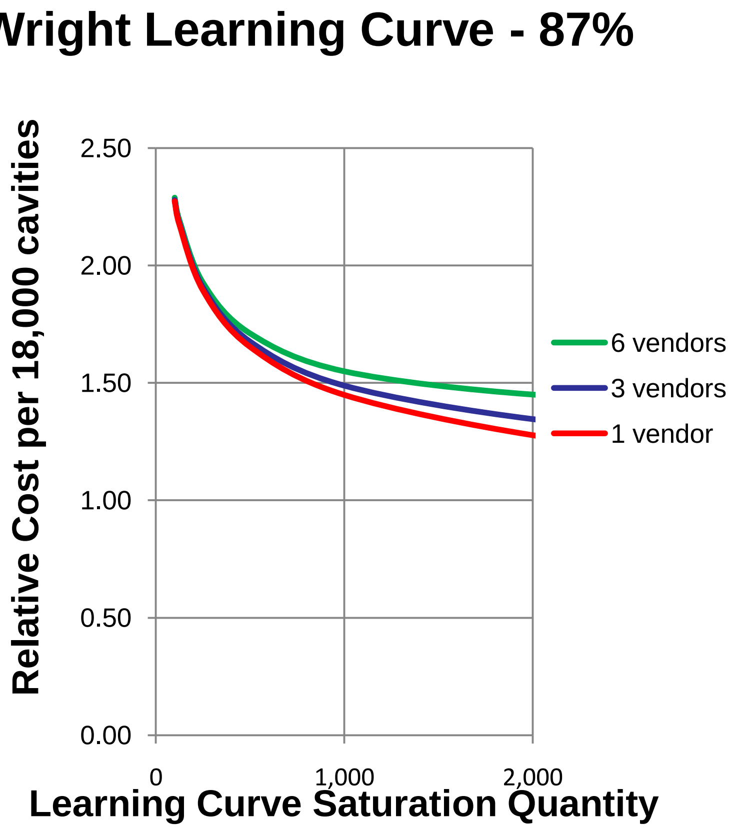
Learning Curves - continued



87% Wright LC for 18,000 cavities	1 vendor 18,000	3 vendors 6,000 ea	6 vendors 3,000 ea
LC continues forever	RDR = 1.00	1.25	1.43
LC saturates at 1/3	1.08	1.35	1.54
LC saturates at 100 units	2.27	2.28	2.29

how does integrated cost depend on where saturation of L.C. occurs?





How does this apply to ILC?

- What are we scientists & engineers supposed to do?
- We have no high volume industrial experience
- Dan Adelman (Chicago/Business) reminds us of the obvious: ***Ask someone who is experienced!*** e.g.
  - **Babcock-Noell – they do this & did TESLA/XFEL study**
  - **ACCEL/RI & Zanon – what did their XFEL bids say?**
    They will have lots of experience from XFEL,
    will they share it with ILC? (proprietary?)
  - **Mitsubishi "industrial layout research section"**
    optimize plants & processes to maximize MHI profit
    Akira should ask them for C(18K,1) vs. 6*C(3K,1)
  - **Boeing 787 & Airbus for internationalization**

added after Peter's Paris presentation

Feedback from Peter G's presentation on Cost Estimating for Industrial Production of Cavities

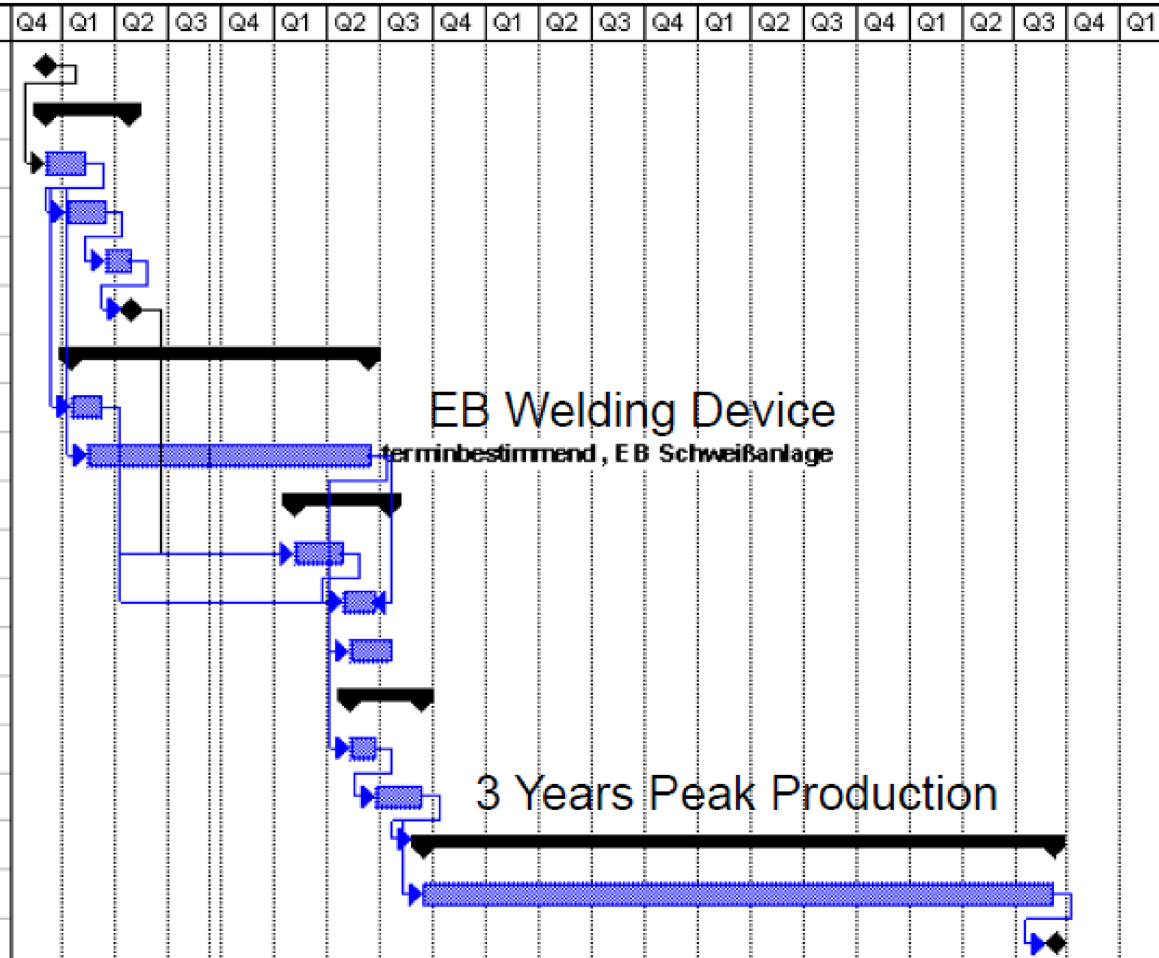
- we need to understand cost and advantages/disadvantages of 1 or 6 vendors
- we need new or updated industrial studies
  - both by top-down (from integrators like Noell-Babcock, General Dynamics)
  - and bottom-up (by component manufacturers like ACCEL, ZANON, AES)
- these studies are needed in 2011, but where are the resources (costs & ILC manpower)?
  - we also must update RDR estimates based on XFEL experience and plans
  - if we do not present these models and their impacts, we will not be taken seriously

Akira: make sure same production timescale is required for each C(18K,1) & C(3K,1) estimate

- What is the optimal production timescale?
  - likely to be at the longest time limit in order to minimize cost of infrastructure.
- ILC will have to determine this constraint.
- Can we ask for Cost vs. Time and then ILC optimizes, considering both cost & time impact?
- Similarly, how do learning curves depend on timescale for production?
- Babcock-Noell TESLA study had 20,000 cavities
  - 6.5 years total & ***production over 3.5 years***

Cavity Production Schedule

Nr.		Vorgangsname
1		1 Projektstart
2		**2 Planung**
3		2.1 Anlagenauslegung u. Planung
4		2.2 Gebäude u. Energieversogungsplanung
5		2.3 Baugenehmigungen
6		2.4 Freigabe zur Errichtung
7		**3 Beschaffung** Procurement
8		3.1 Betriebsgelände Auswahl
9		3.2 Maschinentechnik
10		**4 Errichtung** Construction
11		4.1 Gebäudetechnik
12		4.2 Infrastruktur
13		4.3 Maschinentechnik
14		**5 Inbetriebnahme** Preproduction
15		5.1 Kalte Inbetriebnahme
16		5.2 Warme Inbetriebnahme
17		**6 Produktion**
18		6.1 Vollastbetrieb
19		6.2 Produktionsende



discussion