LARP

Overview & Accelerator Systems

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LARP

Introduction

U.S.-LHC Accelerator Research Program

Why do LARP if there is no VLHC?

1) Superconducting magnet R&D is a strategic technology

- apply a focus to the U.S. national effort

2) Junior accelerator physicists are a strategic resource

3) Participate in state-of-the-art accelerator science

- in the tunnel & in the control room on the frontier

Items 2 & 3 support the ILC (& future Hadron Colliders)

Why discuss LARP here?

"(R)eview of ... LARP will not formally be part of this review, but you ... should understand and evaluate whether the overall scale and scope ... is appropriate to an optimum overall accelerator R&D program ... ."

LARP success is co-dependent on the "base" or "core" programs at BNL, FNAL, LBNL & SLAC.

This is especially true for Magnet R&D

LARP

Mission statement

1) Make more LHC luminosity, earlier

2) Use and develop unique U.S. resources

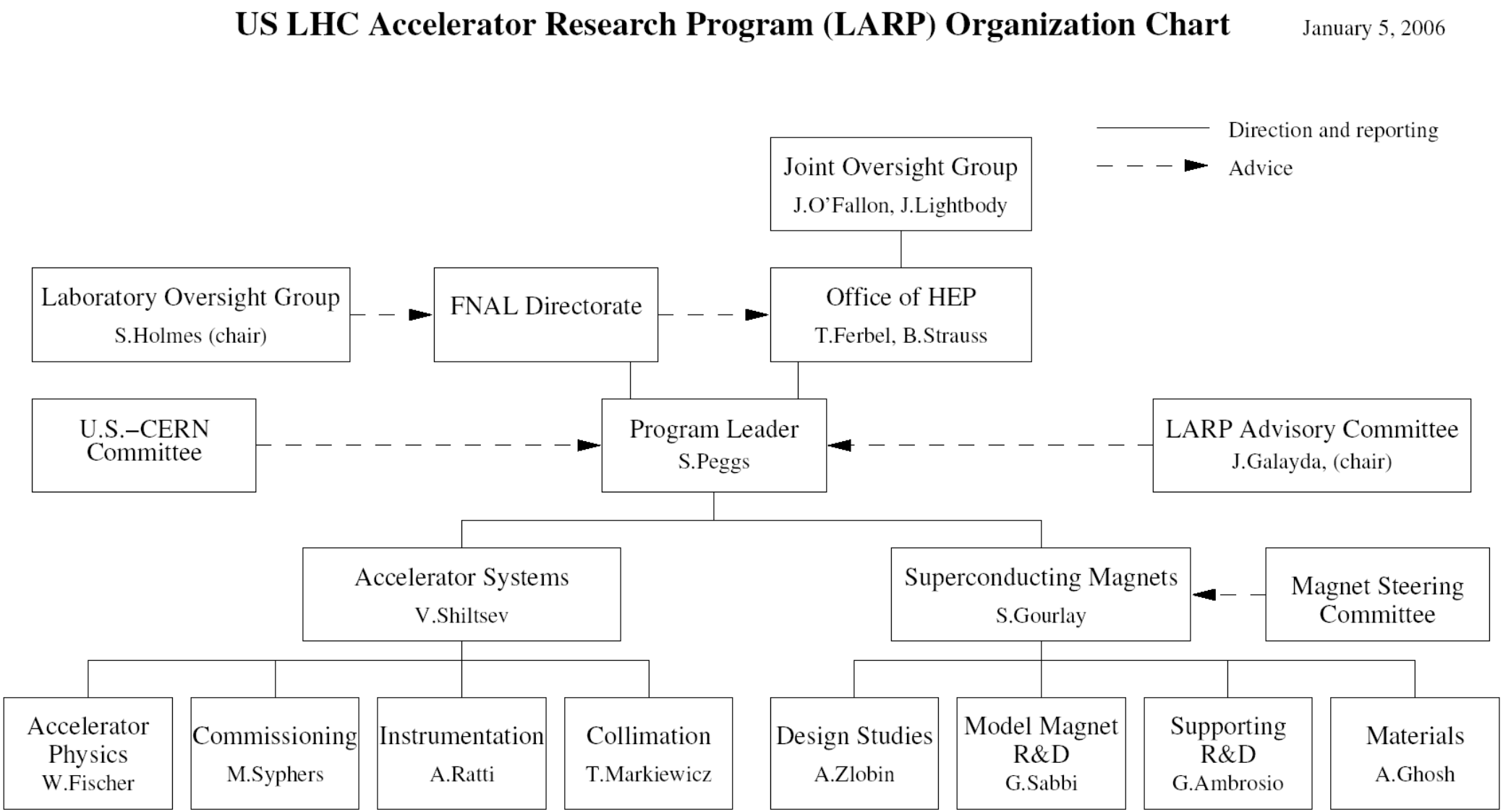
3) Advance the state-of-the-art of accelerator science

4) Involve U.S. physicists in beam commissioning

5) Develop supercon magnets for a luminosity upgrade

6) Make more LHC luminosity, later

Kid sister to U.S.-CMS & U.S.-ATLAS



FY06 allocations

LARP FY06 budget request v2a

Sept 11, 2005			FY2006				
WBS			BNL	FNAL	LBNL	SLAC	Total
US LHC Accelerator Research Program			**2838**	**3207**	**3975**	**780**	**11000**
1	**Accelerator Systems**		**855**	**1150**	**1255**	**700**	**3960**
1.1	**Instrumentation**	**Ratti**	345	250	935	0	1530
1.2	**Acc. Phys. & Comm.**	**Syphers**	410	850	320	0	1580
1.3	**Collimation**	**Markiewicz**	100	50	0	700	850
2	**Magnet R&D**		**1543**	**1787**	**2320**		**5650**
2.1	**Design Studies**	**Zlobin**	83	190	105		378
2.2	**Model Magnet R&D**	**Sabbi**	0	1334	1063		2397
2.3	**Supporting R&D**	**Ambrosio**	1282	67	504		1853
2.4	**Materials**	**Ghosh**	178	196	648		1022
3	**Program Management**	**Peggs**	**440**	**270**	**400**	**80**	**1190**

Guidance “flat” at $11M -> $12 M in FY07 and beyond

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Accelerator Systems

Portfolio

About half of LARP funding goes to Accelerator Systems:

- Beam diagnostics instrumentation
- Accelerator Physics theory, simulations & expts
- Commissioning
- Collimation

The other half of LARP is long term Magnet R&D for LHC Interaction Region Upgrade

- integrated with Accelerator Physics studies
- "school of hard knocks": how will LHC really behave?

Many potentially worthwhile tasks fall off the LARP list ...

Accelerator Systems tasks

Commissioning challenges (identified):

Luminosity	Challenge	LARP activity
Small	Snap-back	Tune Feedback
Medium	Stored energy	Collimation
Nominal	Beam-beam	Lens, wires, ...
Upgrade	Debris power	IR Upgrade

LARP Accelerator Systems tasks are linked to these early challenges, and to middle term enhancements

Later (2012?) comes an Interaction Region upgrade. Magnet R&D proceeds **now,** to be ready **then.**

LARP will be judged against the great success of the U.S. LHC Construction Program that has (almost) wound down

Extrapolating from Tevatron to LHC

		Tevatron [Feb 06]	LHC [“nominal”]
Luminosity [$\mathrm{cm}^{-2}\mathrm{s}^{-1}$]	L	1.7×10^{32}	1×10^{34}
Magnet style		1-in-1	2-in-1
Beam-Beam parameter	ξ_1	0.010	0.004
	ξ_2	0.002	0.004
Number of bunches	M	36	2,808
BUT unfortunately ...			
Beam stored energy [MJ]		1	366
Chromaticity snap-back	$\Delta\chi$	~ 30	~ 300
Debris power [W]		~ 1	~ 900

“Snap-back” transients

To keep even a little beam in the machine one must:

- keep the beam in the middle of the pipe
- control the horizontal and vertical free oscillation “tunes”, or frequencies
- control the “chromaticity” of the optics (all particles must have the same tunes)

Normally these quantities are almost stable

- except for snap-back transients at the beginning of acceleration from 1 TeV to 7 TeV

For fundamental reasons, these transients are very strong in the LHC

How much is 350 MJoules?

Kinetic energy

- 1 ship of 10,000 tonnes going 30 kph
- 450 automobiles of 2 tonnes going 100 kph

Chemical energy

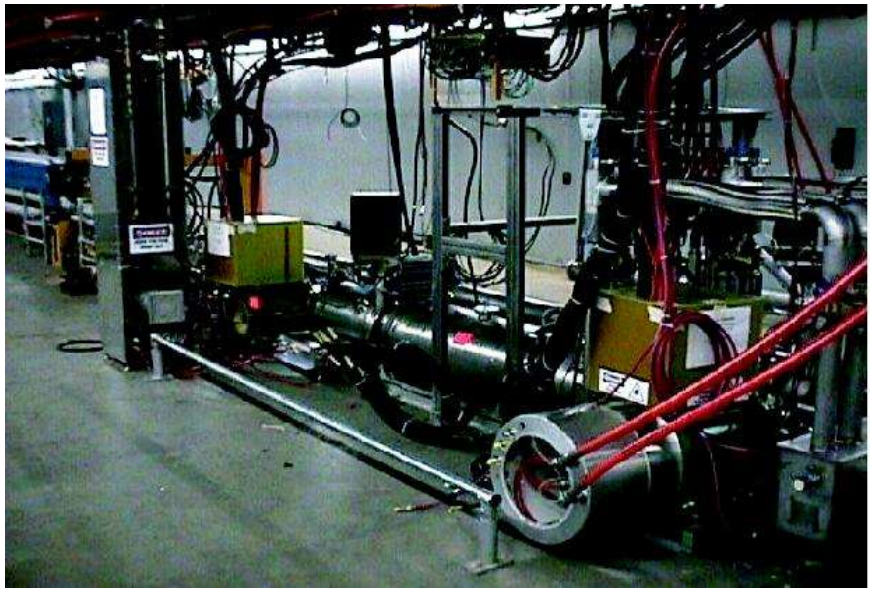
- 80 kg of TNT
- 70 kg of (swiss?) chocolate

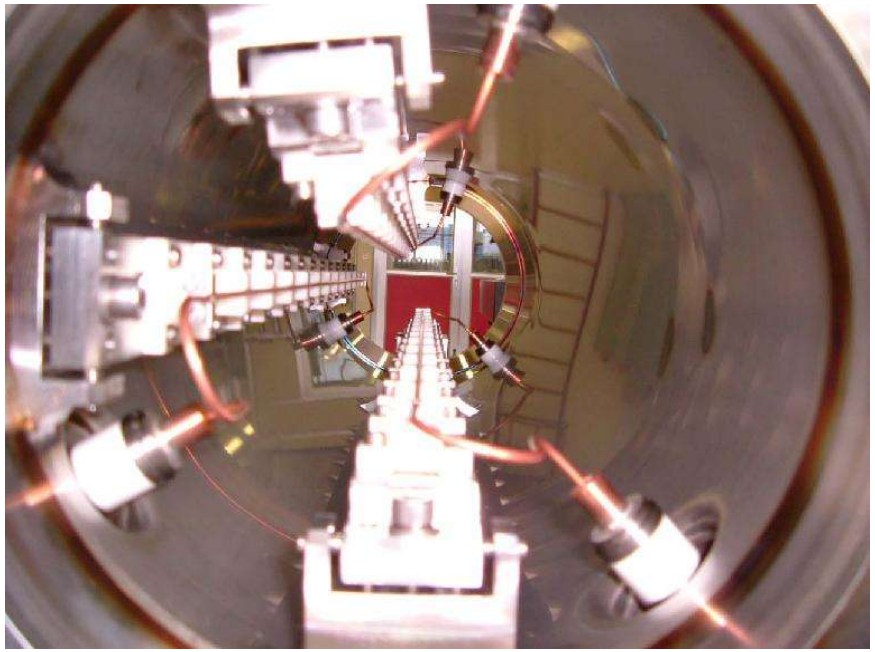
Thermal energy

- melt 500 kg of copper
- raise 1 cubic meter of water 85 C: “a tonne of tea”

Only strict control of beam losses will avoid component damage (eg magnets) with modest beam intensities

Beam-beam compensation





Beam-beam effect: counter-rotating bunches pass through and disrupt each other

Is direct compensation possible?

U.S. accelerators offer test beds, and themselves would benefit

TOP: "Electron lens" installed in the Tevatron

BOTTOM: "Beam-beam wires" installed in the CERN SPS, and soon in RHIC

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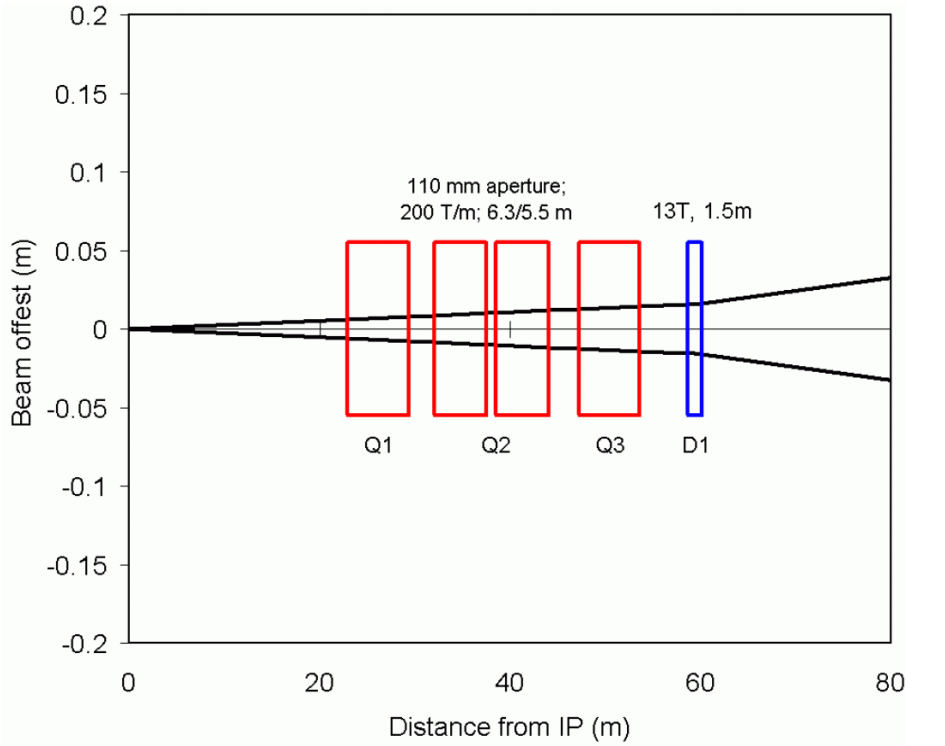
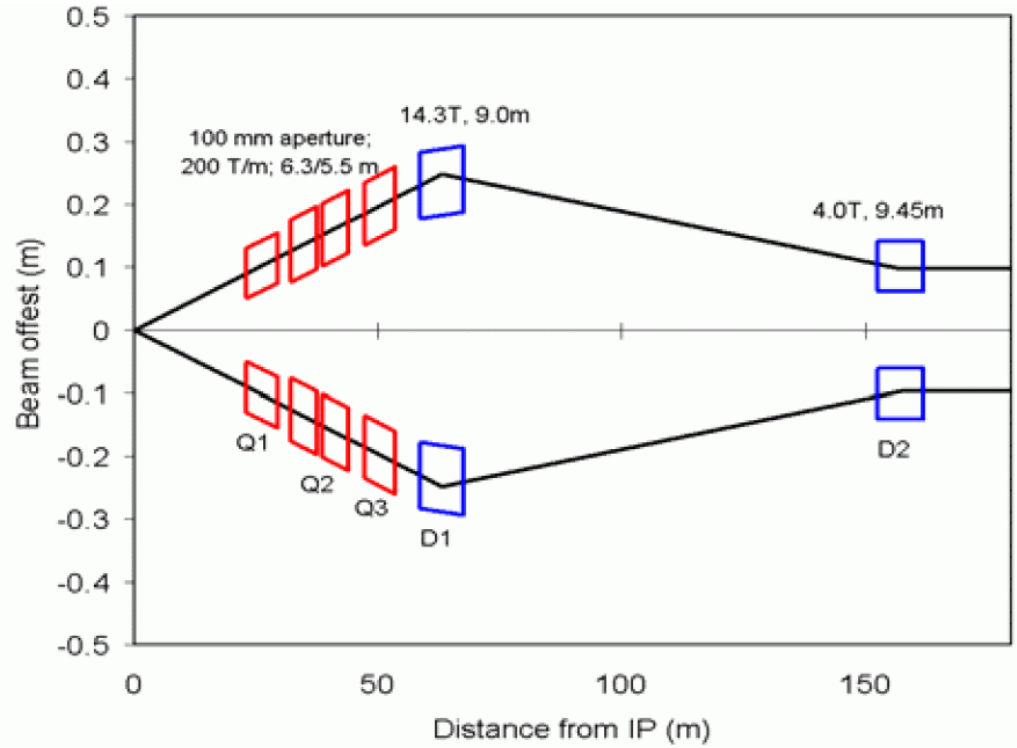
Magnet R&D

Interaction Region upgrades

Conventional (most likely)



Large angle (later upgrade?)



All scenarios require high strength magnets made from Niobium-Tin materials that are still under development!

What is to be done?

"Demonstrate by 2009 that Nb_3Sn quadrupoles are a viable choice for an LHC IR upgrade"

1) demonstrate "short" technology quads
   1 m, ~230 T/m, 90 mm

2) scale up from "short" to "long"
   4 m long racetracks, then TQ cross-section quads

3) develop short strong quads
   1 m, ~300 T/m, 90+ mm

There is no guarantee that 2) and 3) are possible

(LARP would be a success if it proved the contrary??)

Core Programs

Illuminated by comments from the close out of the Directors Review of the FNAL Magnet Program, Jan 06

"LARP cannot be successful without the success of the Fermi program."

"The laboratory's base program in magnet development is now almost all at the service of LARP."

"The base program mitigates risk by providing viable alternatives to activities in LARP that for budgetary reasons are singular and perhaps risky."

"The management of the Fermilab Technical Division ... should be complemented for the synergy ... that leverages the impact of the U.S. investment on the LHC future."

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Junior Workforce

Strategic Resources

U.S. leadership/presence at the frontier of strategic enabling technologies (eg SC RF & magnets) requires:

1) a vibrant R&D program focused on LHC & ILC
2) deliberately tended junior workforce pipeline

U.S. labs house large accelerators untenable at universities

- CEBAF (TJNL), PEP (SLAC), RHIC (BNL), Tev. (FNAL)

The education of accelerator physicists & engineers is more centralized than HEP theory or experiment

- reality bites: the best education is the new real world
- intelligent junior staff vote with their feet, and go to the cutting edge accelerator du jour, eg LHC

Junior workforce pipeline

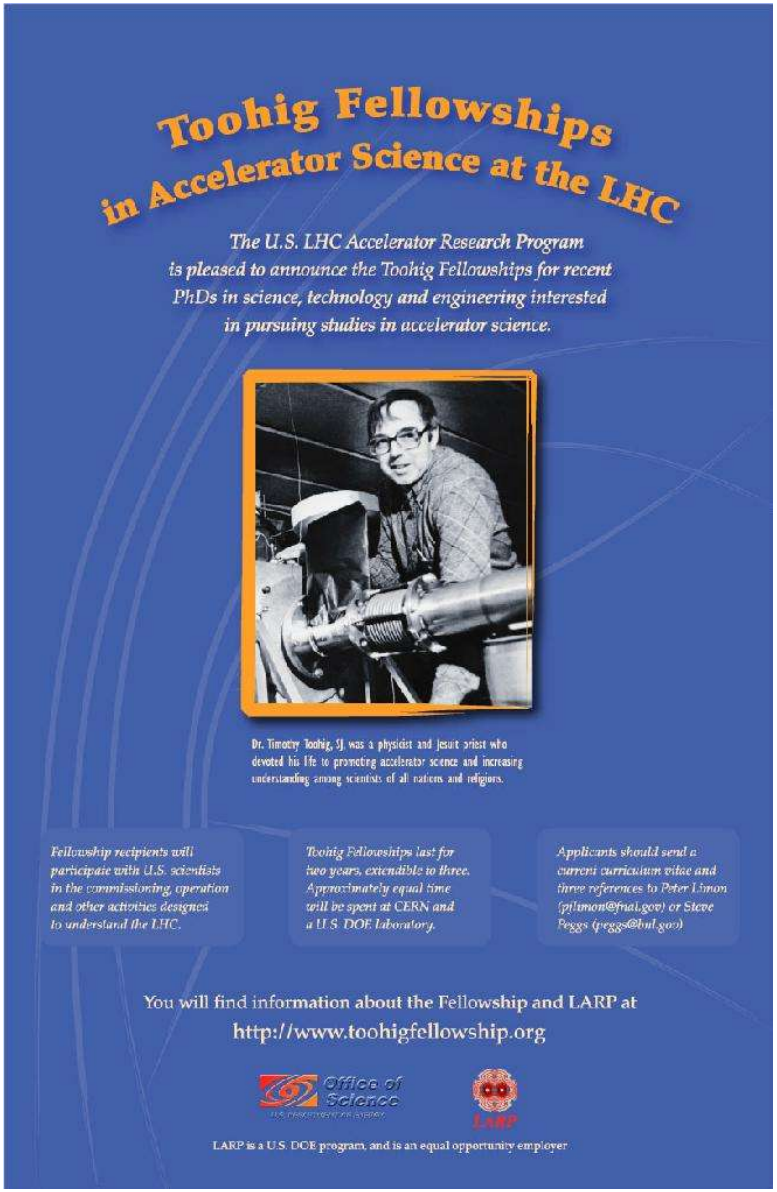
LARP must help to

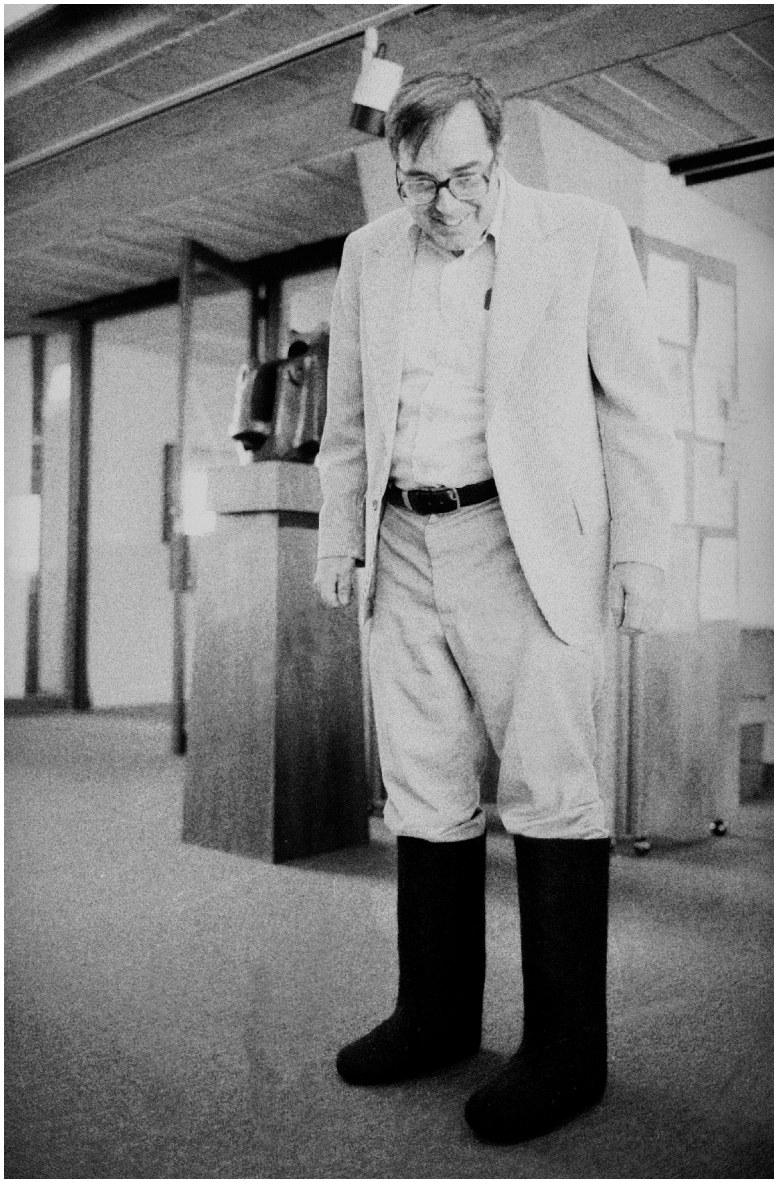
- hire the best young staff to U.S. labs
- place them for long stays at LHC (50% duty factor)
- attach them to strategic R&D
- show a path to permanent positions for non-Europeans

There is a natural evolution from LHC to ILC

- unless LARP deliberately tends the junior workforce pipeline, U.S. Labs and U.S.-ILC efforts will suffer

Toohig fellowships for the best & brightest





BNL/Stony Brook

Dragt/Kim Survey: "One of the elements in the charge to this subpanel addressed education and training."

Litvinenko: "... (the) past, present and future needs for good accelerator scientists exceed the present capacity of educating them."

Ben-Zvi: "On average the future need for Accelerator Scientists will continue to grow. Although it is clear that it must reach saturation, we are still far from that point."

Ben-Zvi: "... there are not enough accelerator scientists, since it is difficult to recruit a good (young) scientist when you need one."

Summary

Summary

1) Why do LARP?
   - Superconducting magnet R&D is a strategic technology
   - Junior workforce is a strategic resource
   - Participate in frontier accelerator science

2) LARP success is co-dependent on the “base” programs

3) Accelerator Systems tasks are linked to early challenges and mid-term enhancements

4) Later (2012?) comes an Interaction Region upgrade.
   - Magnet R&D proceeds **now,** to be ready **then.**
   - Demonstrate by 2009 that Nb_3Sn quads are viable.

5) LARP deliberately tends the junior workforce pipeline
   - otherwise, U.S. Labs and U.S.-ILC efforts will suffer