Status of 2G Manufacturing & Development at SuperPower

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Program funding from Title III and DOE through UT-Battelle, AFRL, & AFOSR

HTS Solutions for a New Dimension in Power

DOE Wire & Applications Workshop, Panama City, FL, January 16 - 17, 2007

Clear advantages to switching from 1G to 2G

Better in-field performance

Better mechanical properties

- Higher critical tensile stress
- Higher bend strain
- Higher tensile strain

Better engineering current density

Lower ac losses

……but,

270 m long, 4 mm wide
2G conductor with Ic of 100 A

Je = 26 kA/cm^2 ~ 2x Je of 1G

…first, 2G needs to be on par with 1G in several key areas

Key areas where 2G needs to be competitive with 1G within the next 2 years in order to be used in the next round of device prototype projects:

- Long piece lengths
- Critical current over long lengths
- Availability
  - High throughput (= production volume/year)
  - Demonstration of large deliveries from Pilot-scale production
- Cost comparison with 1G

Attribute	1G	2G (Aug 06)	2G goal (June 08)
Piece length (m)	1,500	300	1,000
Ic (A) in 4 mm over long lengths	200	100	200
Capacity (km/year)	< 1,000	350	1,000*

Our focus in 2006 has been to make significant progress in all key benchmarks

*1000 km/year at the specified length & Ic

Benchmark 1 for Low Cost 2G

Higher Critical Currents

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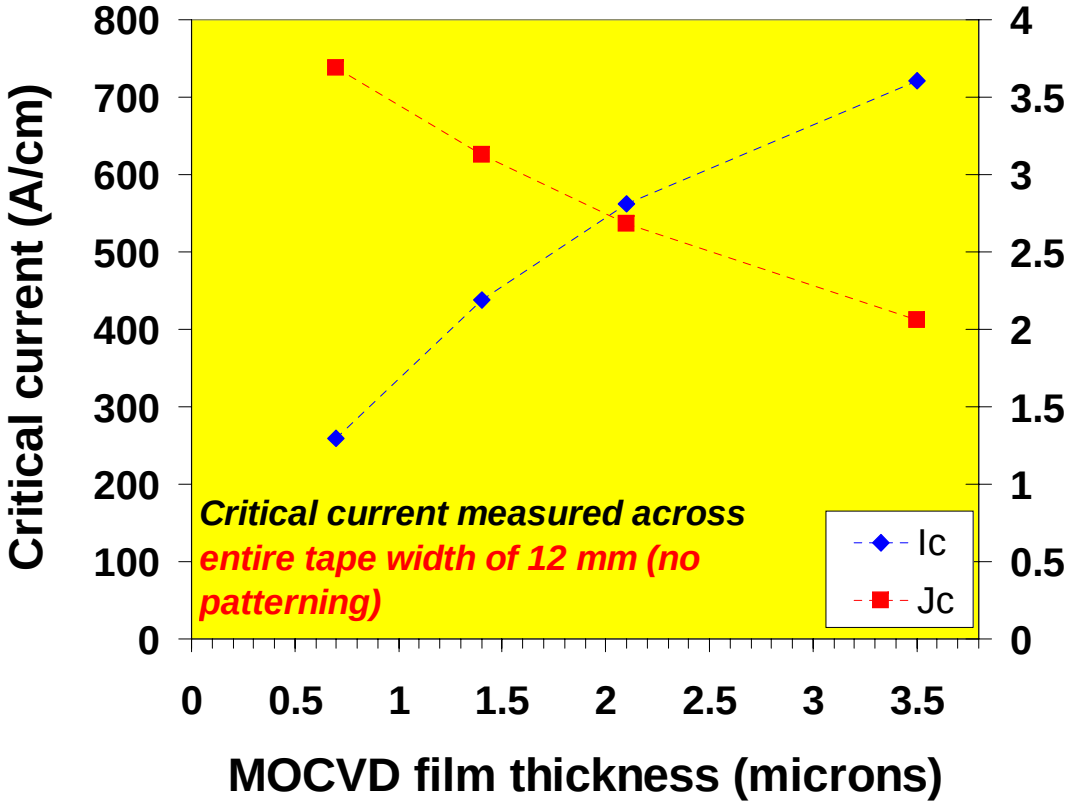
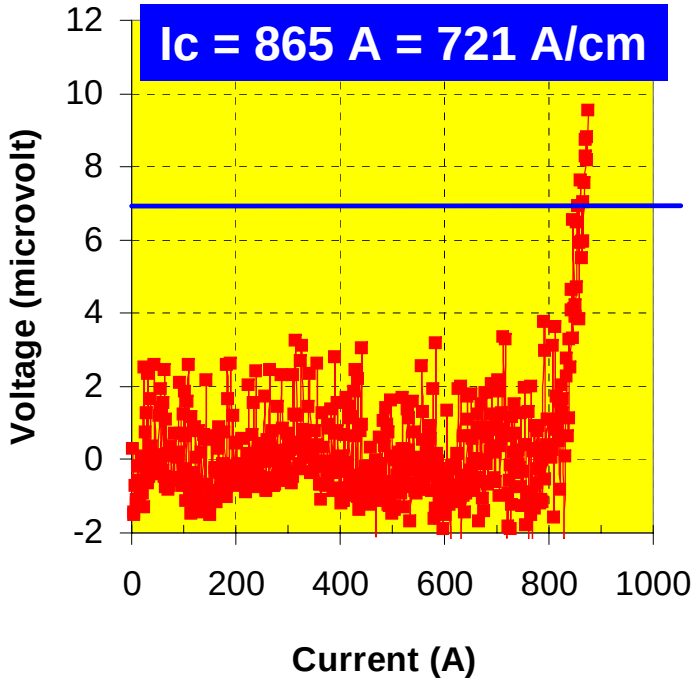
Critical current of 721 A/cm achieved over 7 cm of *continuous, reel-to-reel processed* MOCVD conductor





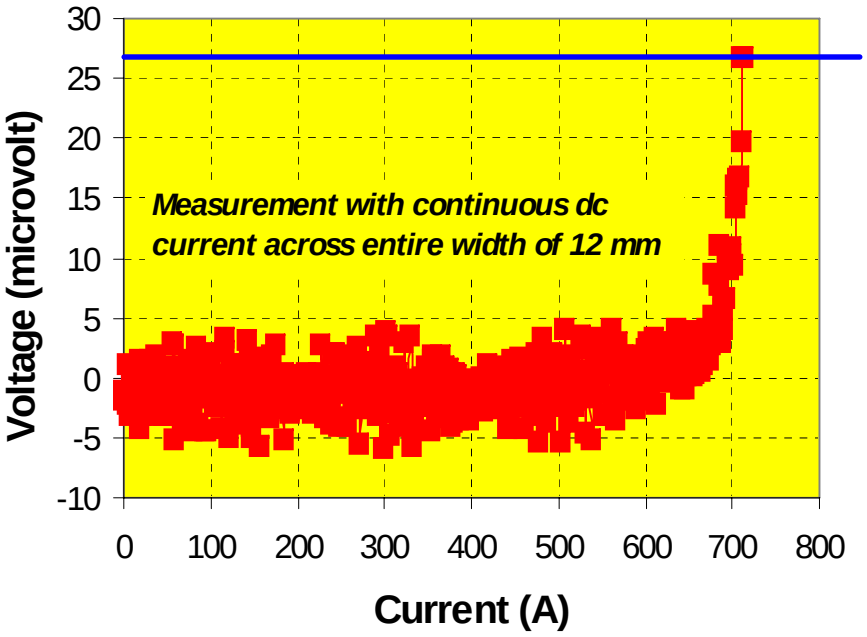
Ic measurement using continuous dc current (no pulsed current) across entire tape width of 12 mm No patterning

In a 3.5 micron film made in 5 passes, achieved Ic of **721 A/cm** **(Jc = 2.06 MA/cm²)** over 12 mm wide, 7 cm long tape.

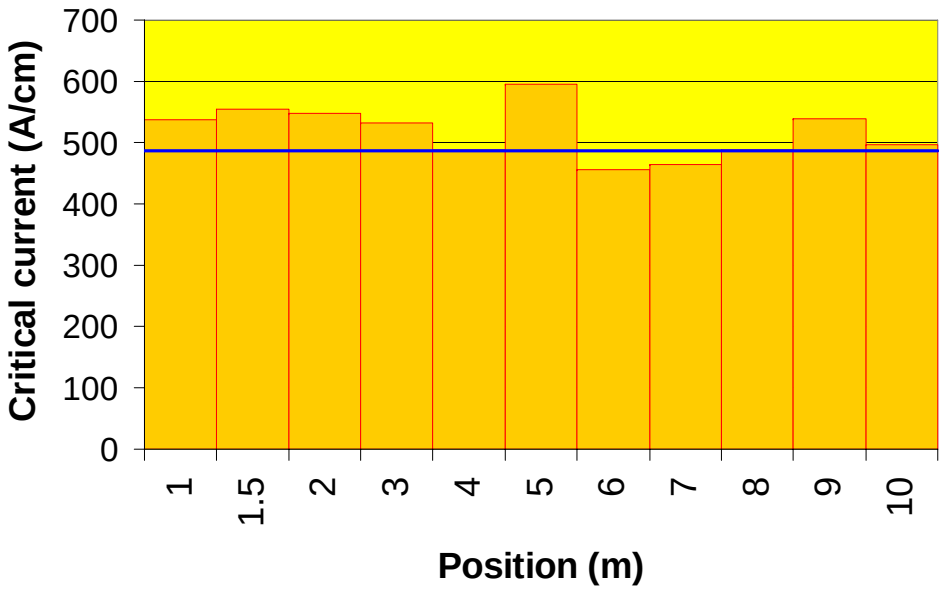
Scaled up thick film MOCVD process to longer lengths with high currents

4-pass MOCVD process for a total HTS film thickness of 2.8 microns

Over 1 m length,
714 A at 0.27 μV/cm = 595 A/cm



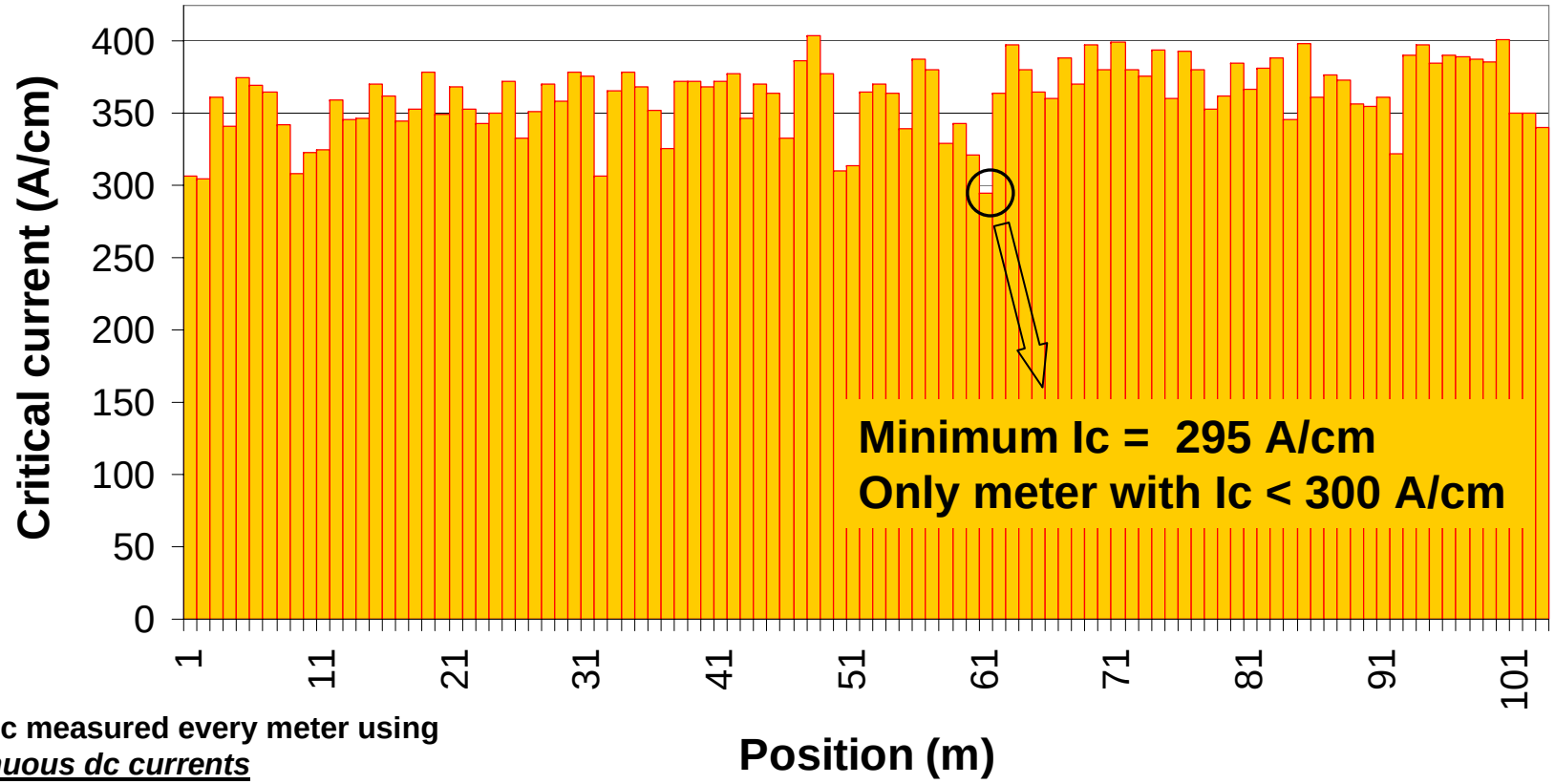
Over 11.1 m length,
End-to-end Ic of 583 A at 1 μV/cm = 486 A/cm



Demonstration of the feasibility of 200 A in a 4 mm wide tape in 10+ m lengths

300 A/cm class conductor produced in 100+m lengths

1.4 micron thick HTS film produced in Research MOCVD system



77 K, Ic measured every meter using *continuous dc currents over entire tape width of 12 mm (not slit)*

Minimum Ic over 103 m = 295 A/cm

(End-to-end Ic over 103 m will be > 300 A/cm)

Standard deviation = 6.8%

Average Ic = 362 A/cm

Maximum Ic = 404 A/cm

Benchmark 2 for Low Cost 2G

Availability of Long-length 2G

Higher Throughput

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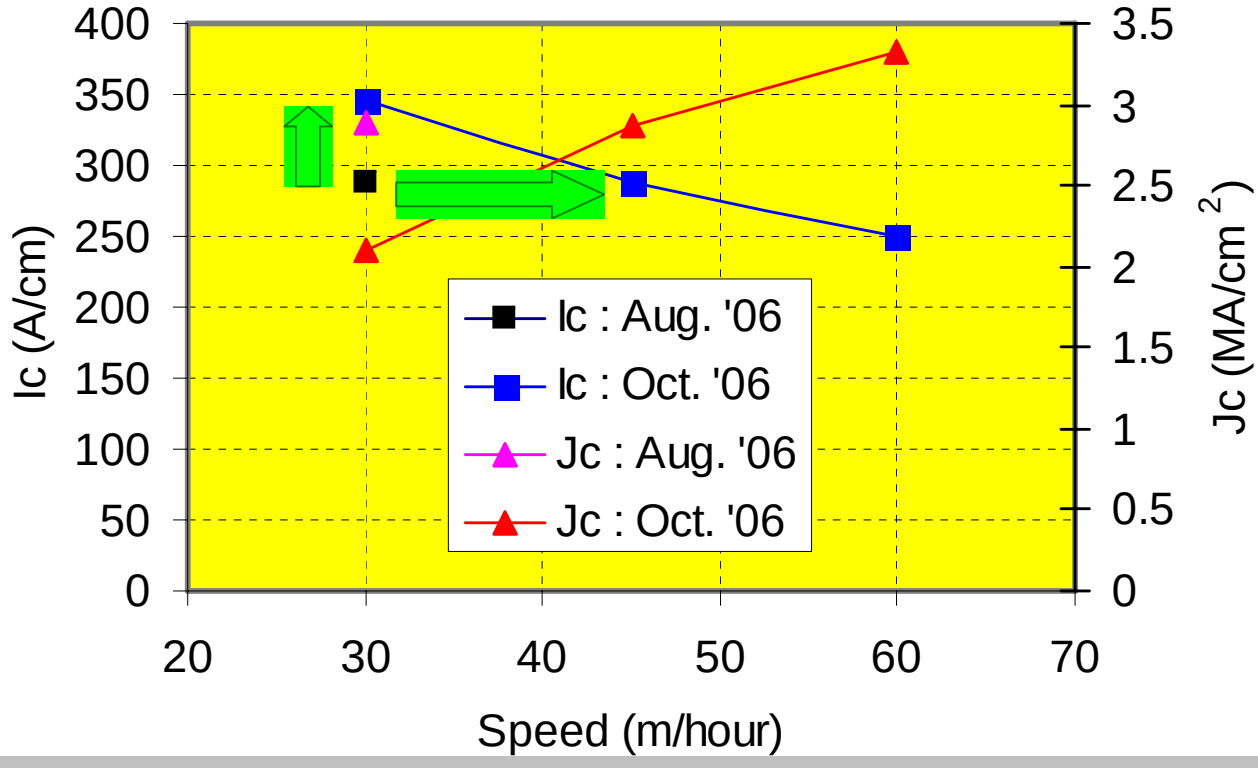
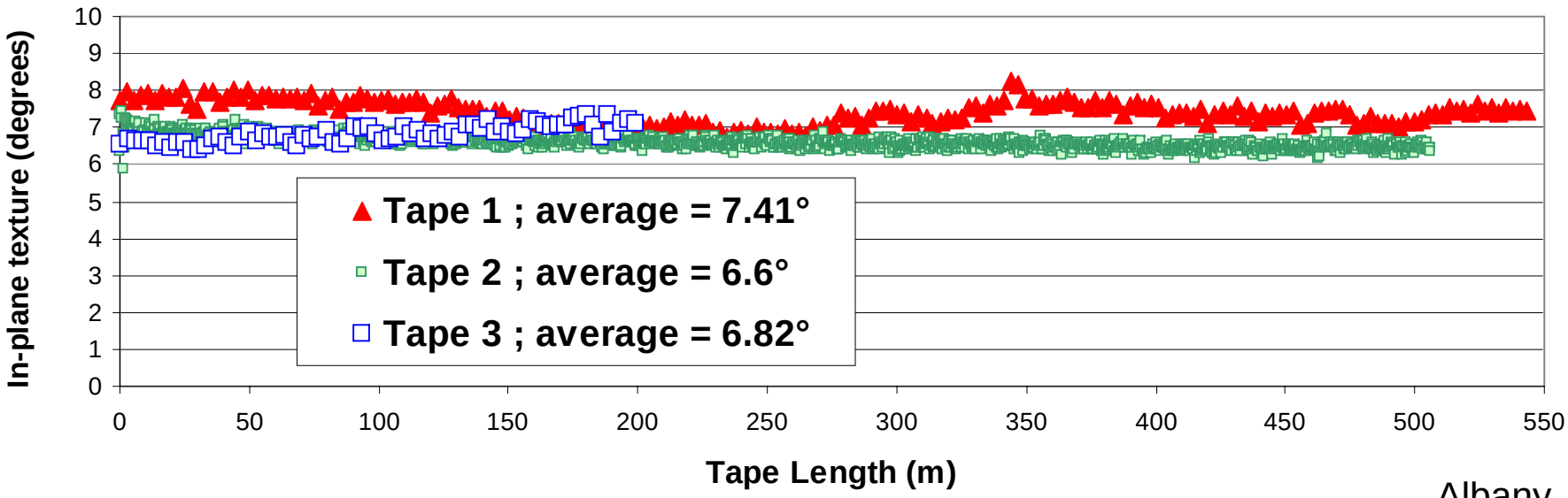
MOCVD tape speed increased by 50% to 45 m/h of 12 mm wide tape (single pass)

MOCVD precursor flow increased by **33%** to achieve 1 micron thick YBCO films at 45 m/h compared to at 30 m/h in Aug. 06. *Same Ic of ~ 285 A/cm achieved at 45 m/h compared to 30 m/h in Aug.06.*

With higher precursor flow, 1.65 micron thick films produced at 30 m/h to achieve a higher Ic of 340 A/cm.



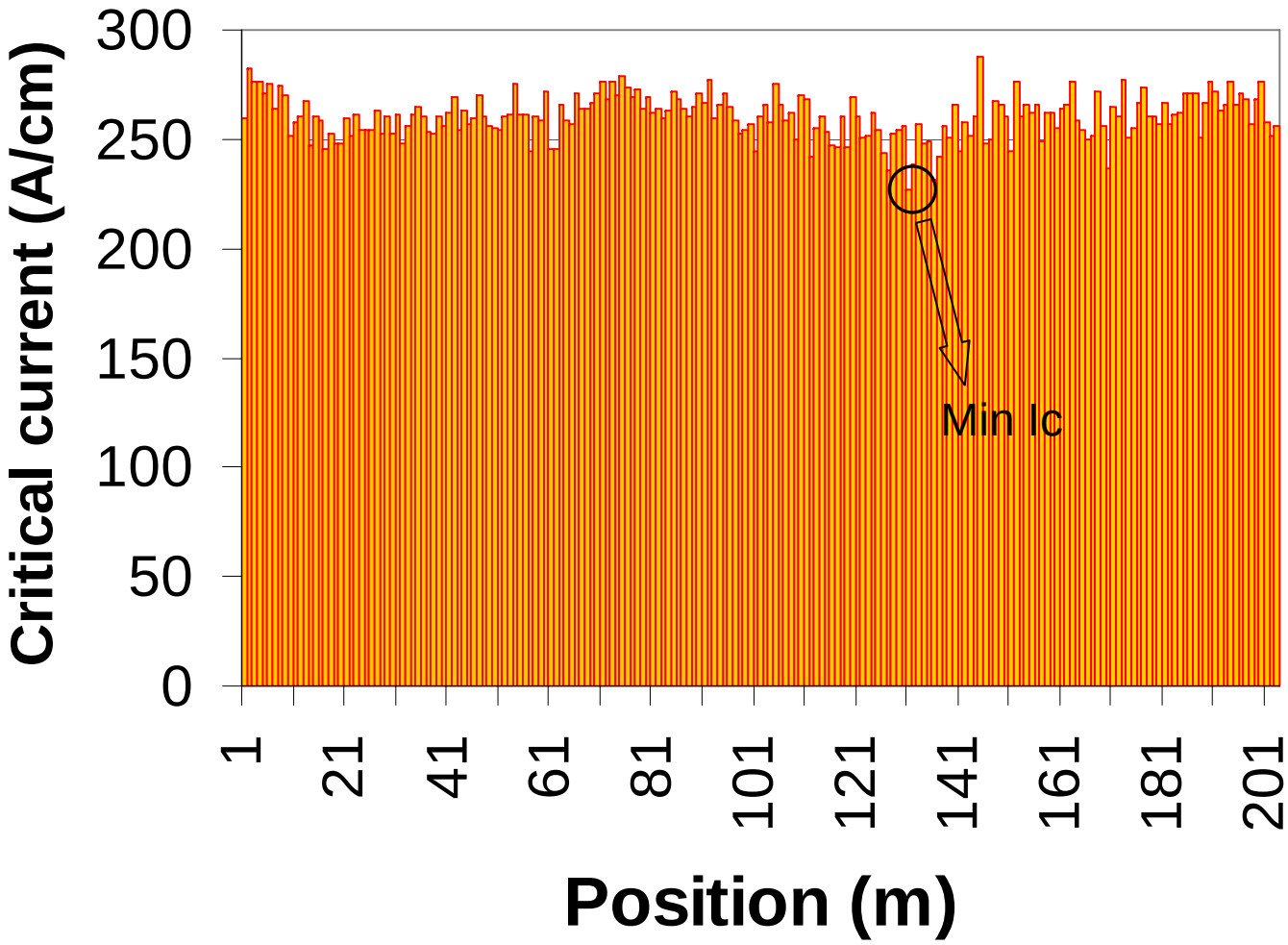
IBAD MgO & Buffer tape throughput increased by 2 to 3x



Tape	Length (m)	Production date	Linear Tape Speed of 12 mm tape (m/h)		
			IBAD MgO	Homo-epi MgO	LMO
1	543	Jun. 06	65	34	40
2	506	Sep. 06	65	60	60
3	200	Oct. 06	120	80	80
4	300	Dec. 06	120	95	120

Albany Cable Project Production

High currents demonstrated over 200+m with all processes at higher speeds



Process	Speed of 12 mm tape (m/h)
IBAD MgO	120
Homo-epi MgO	82
LMO	82
MOCVD	45

Minimum Ic = 227 A/cm over 203 m

Uniformity over 203 m = 3.7%

Benchmark 2 for Low Cost 2G

Availability of Long-length 2G

Demonstration of Large Deliveries from Manufacturing Operations

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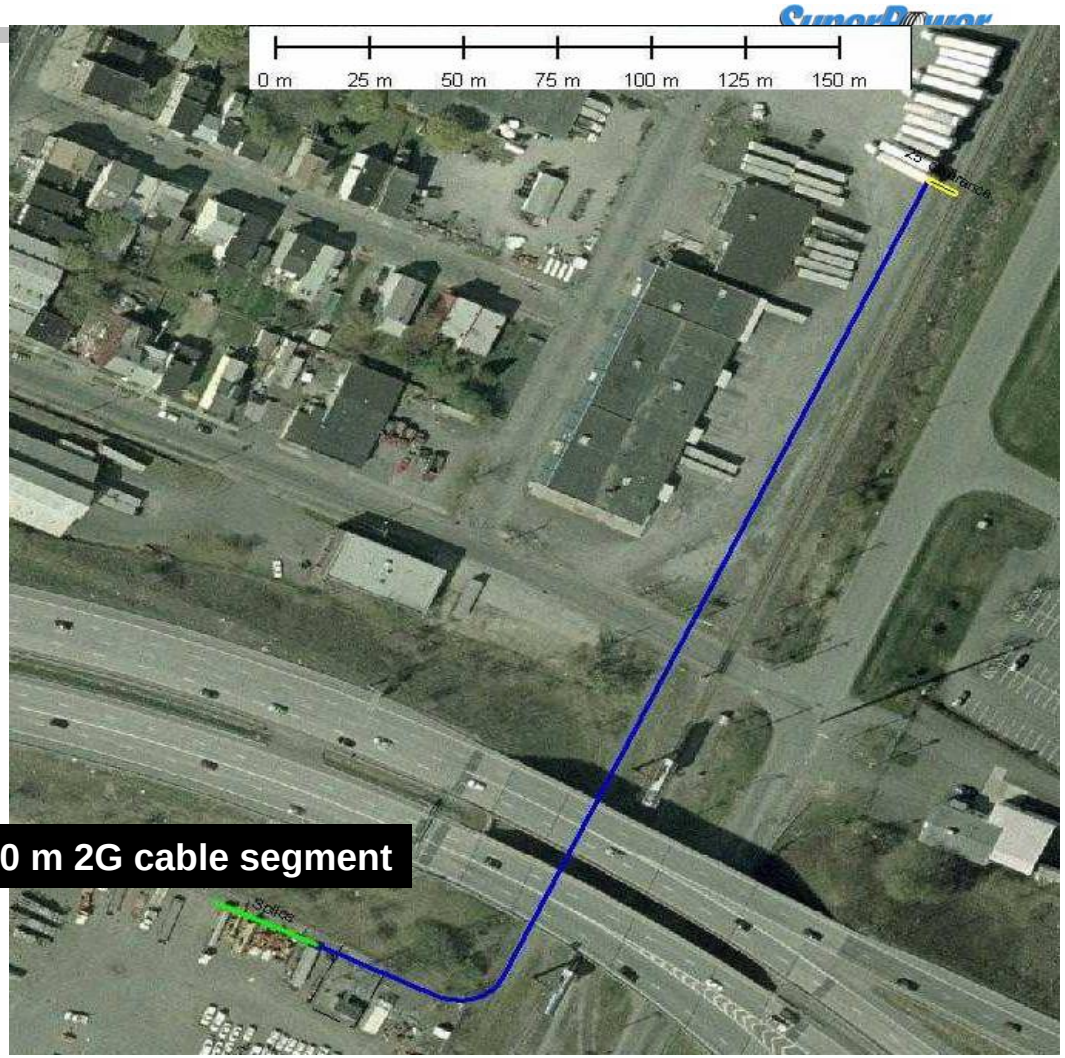
Delivery of nearly 10,000 m of 2G wire for the Albany HTS Cable Project

SuperPower was to deliver 10 km of 2G HTS conductor in 2006 to build a 30 m long cable for the Albany Cable project, which will be the world's first 2G device.

Largest single quantity of 2G delivery

Minimum piece length requirement is 43 m – *not a delivery of tapes from laboratory runs !*

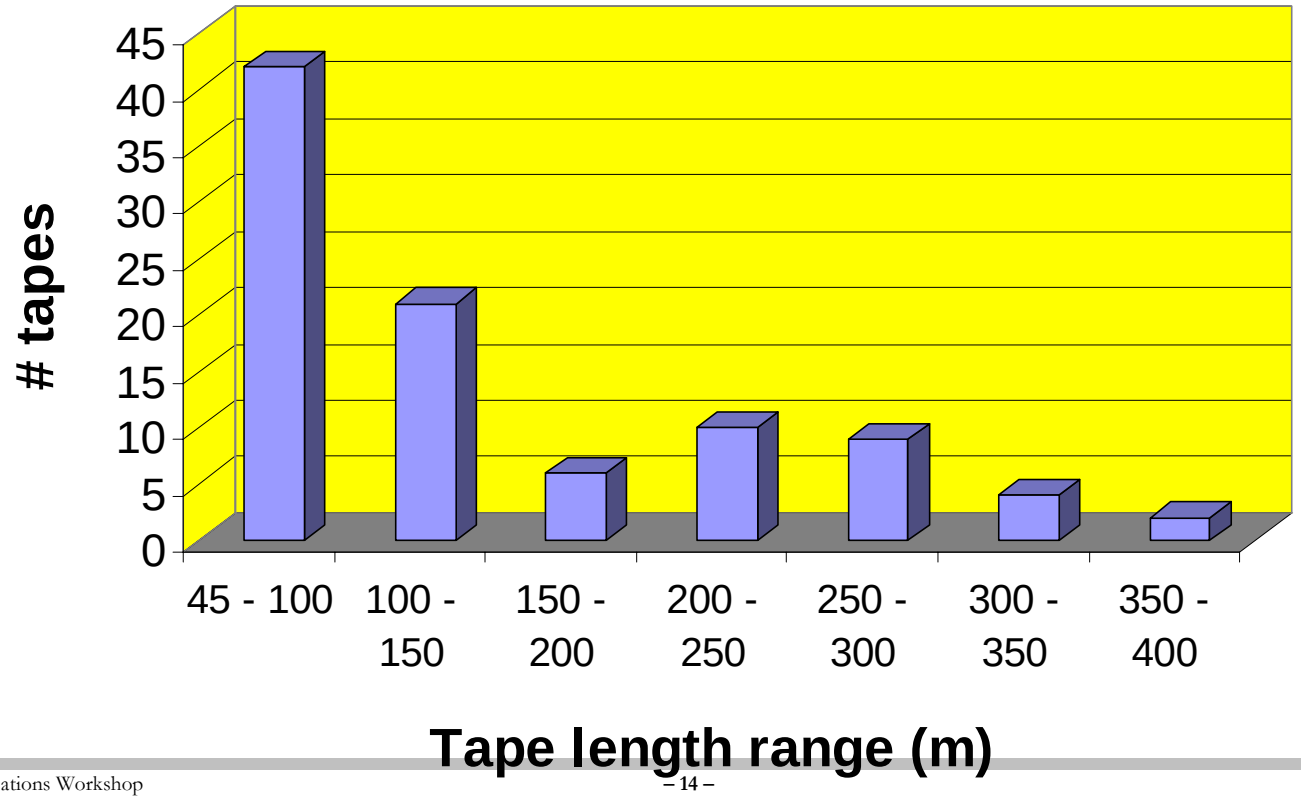
Excellent test for the reproducibility & manufacturing viability of our processes



Albany Cable Project: National Grid, 350 m long cable.

More than 12,000 m of qualified 4 mm slit tape produced by end of July for Albany Cable project

- Piece length required = 42.4 to 44 m;
  Total length required = 9,700 m
- 55% of tapes in inventory > 100 m piece length
- 27% of tapes in inventory > 200 m piece length



Final processing & extensive testing of conductor for delivery

YBCO, 12 mm

Non contact Ic

Transport Ic

Slit, 4 mm

Non contact Ic

Completed in July

Copper Plate

Non contact Ic

Transport Ic

Completed in October

Hermeticity

Mid-October to Mid-December

Selected tapes based on Ic profiles during Nov. – Dec.

Cut to 225 segments each ~ 43 m during Nov. – Dec.

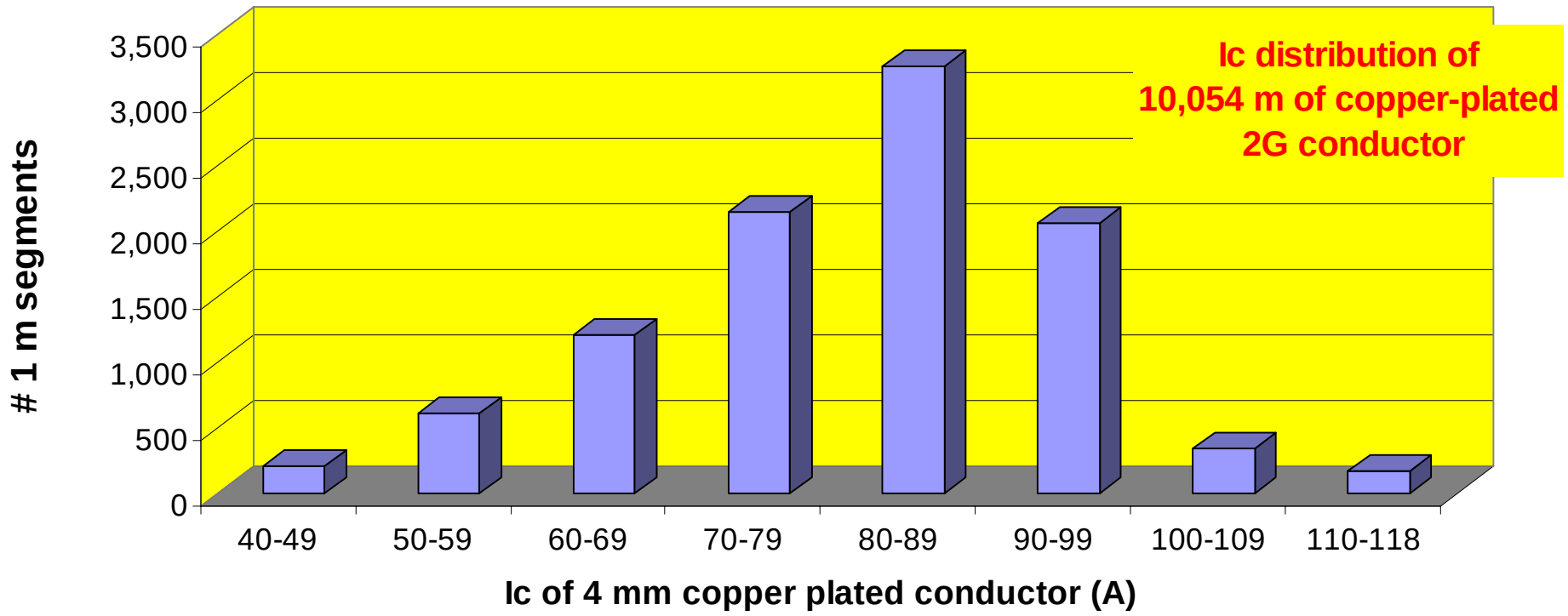
Spot welded 5 m leaders & loaded on individual spools during Nov. – Dec.

Transport Ic & dimensional tests

Non contact Ic

Prepare for delivery

Oct. 06: Completed electroplating of copper stabilizer on 12,000 m and subsequent Ic testing*



Average transport critical current of plated tape in meter lengths = 81 A

80 % of 1 m segments have Ic > 70 A,

58% have Ic > 80 A,

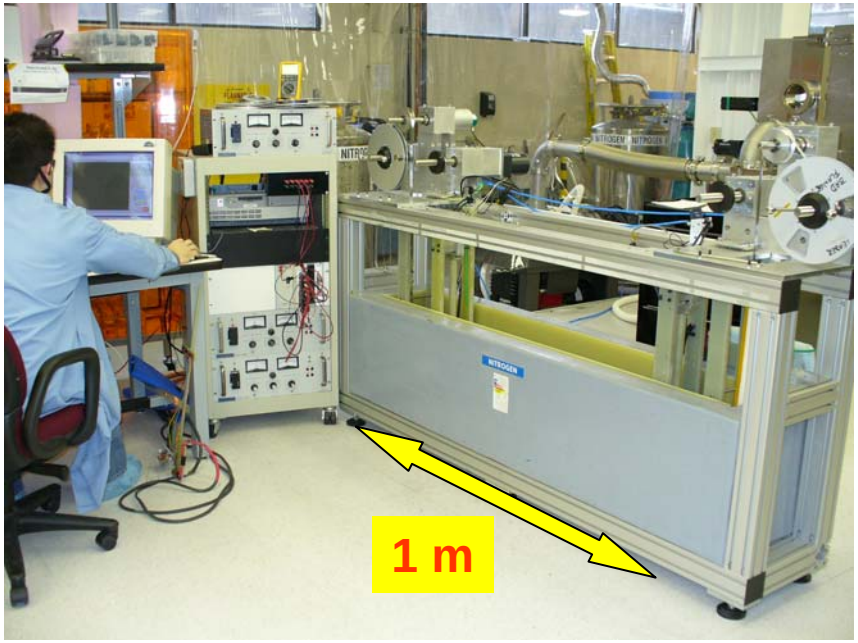
26% have Ic > 90 A

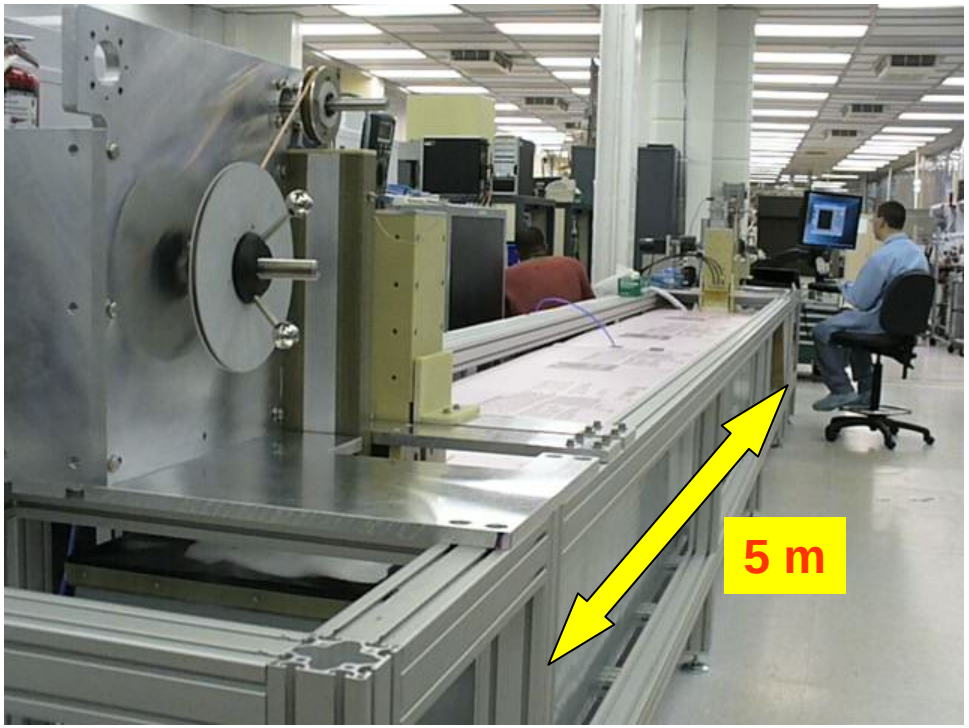
*meter-by-meter Ic & n-value testing

Oct. 06: new test equipment brought into service to meet the high volume needs of production wire delivery

Before Oct. 06: ~ 18 hours to test 400 m. Longest tape length tested in day = 200 m

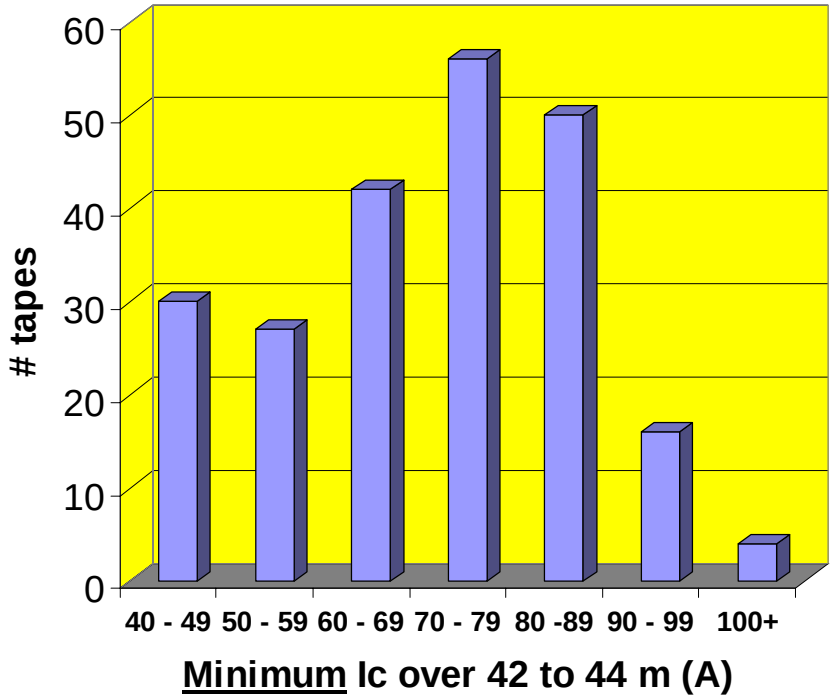
- From June – October 2006: designed & constructed new 5 m Ic rig. Brought rig into full operation in mid-October 2006
- Tested 25,000 meters-equivalent wires in the last two months – averaging 500-600 m/day.
- Obtained Ic, n-value, thickness & width data all in one test run
- Now, time to test 400+ m long < 4 hours. Longest tape length tested in 1 day ~ 1,500 m

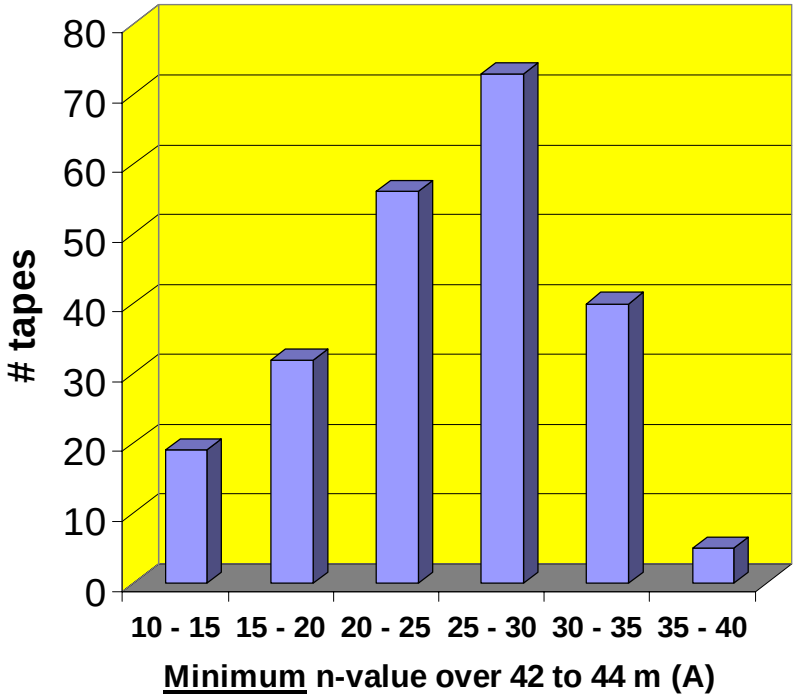




Over 225 segments selected by mid-December

- Tapes were fully qualified for Ic, thickness, width, n-value, and hermeticity
- Average minimum Ic of 225 segments each 42.4 to 44 m long = 70 A
- Over 56% of 225 segments have minimum Ic over 70 A
- Average end-to-end Ic will be higher (~ 2x spec of 40 A)
- Average minimum n-value of 225 segments = 24
- 56% of 225 segments have minimum n-value over 25





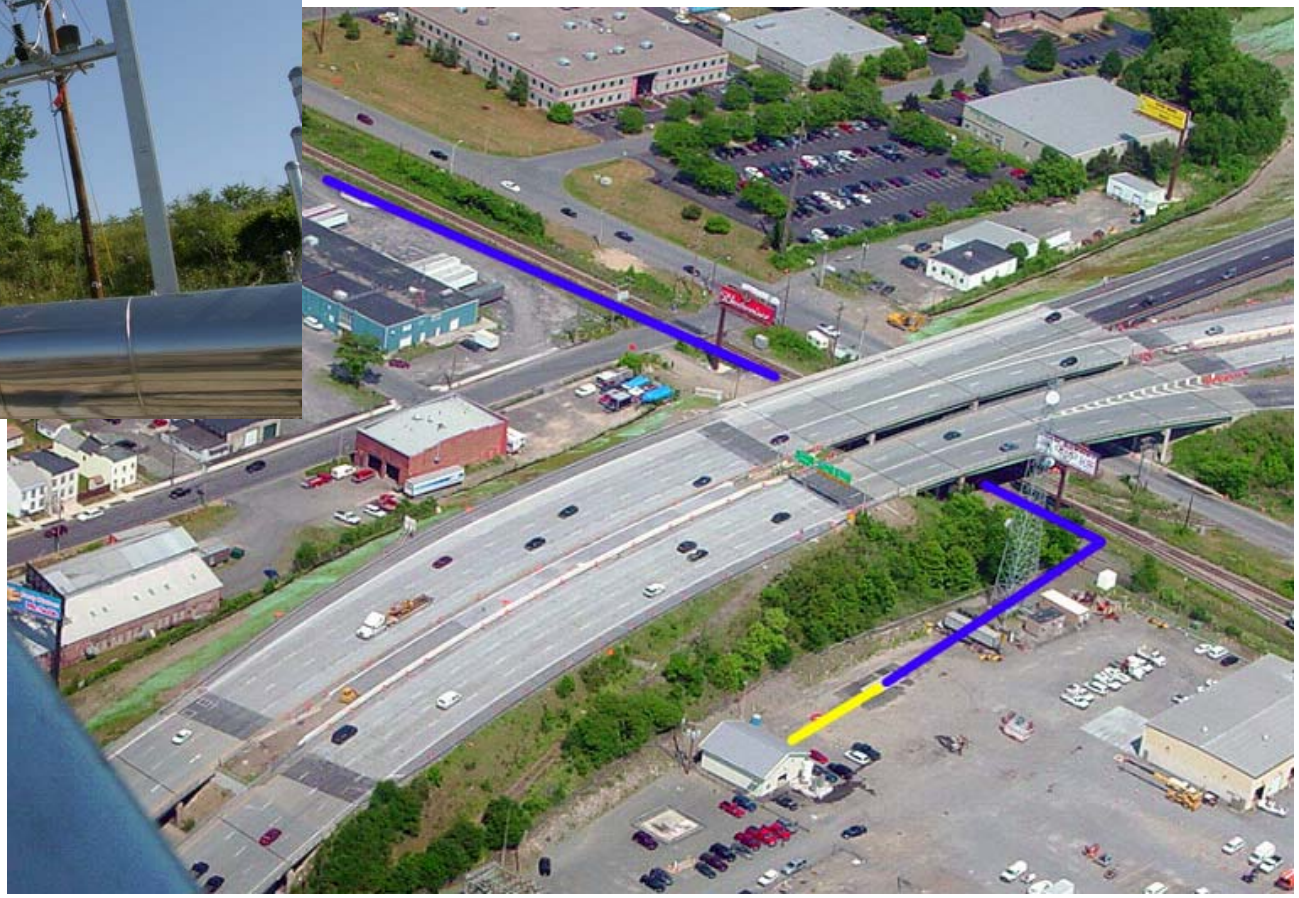
World's first significant 2G wire delivery!

225 segments, each 42 – 44 m long were shipped on Dec. 22, 2006.

Reached Japan on Dec. 28, 2006.

Demonstrated availability of 2G from Manufacturing Operations

30 m 2G Cable to be installed in Albany in 2007



This world's first 2G device will demonstrate the viability of 2G as direct replacement of 1G

Benchmark 3 for Low Cost 2G

Longer Piece Lengths

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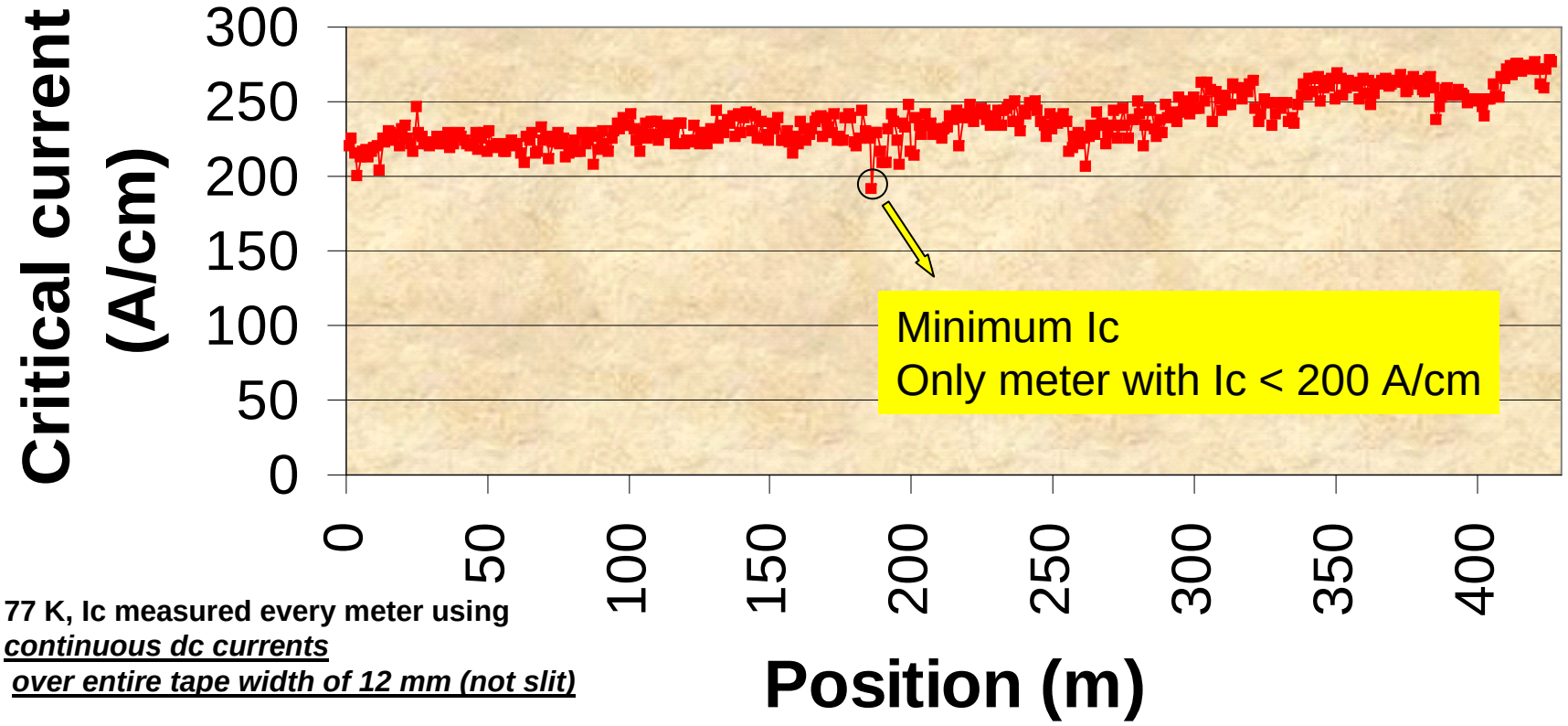
Oct. 2006: 427 m produced by MOCVD at the higher speed of 45 m/h in 1 pass



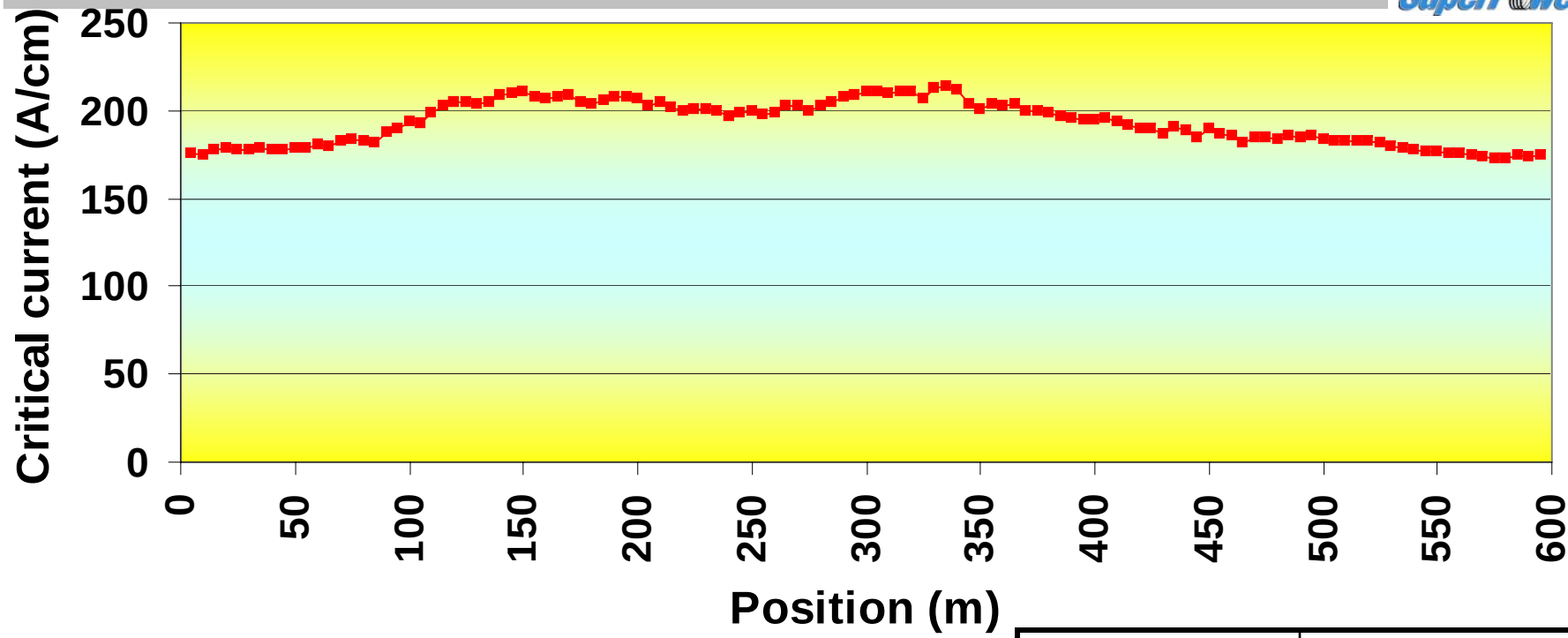
77 K, Ic measured every meter using ***continuous dc currents over entire tape width of 12 mm (not slit)***

Minimum Ic = 191 A/cm over 427 m

Ic × Length = 81,550 A-m

Higher Ic × Length achieved at 50% higher MOCVD speed

Jan. 07: New Milestone reached in 2G Manufacturing



77 K, Ic measured every 5 m using *continuous dc currents over entire tape width of 12 mm (not slit)*

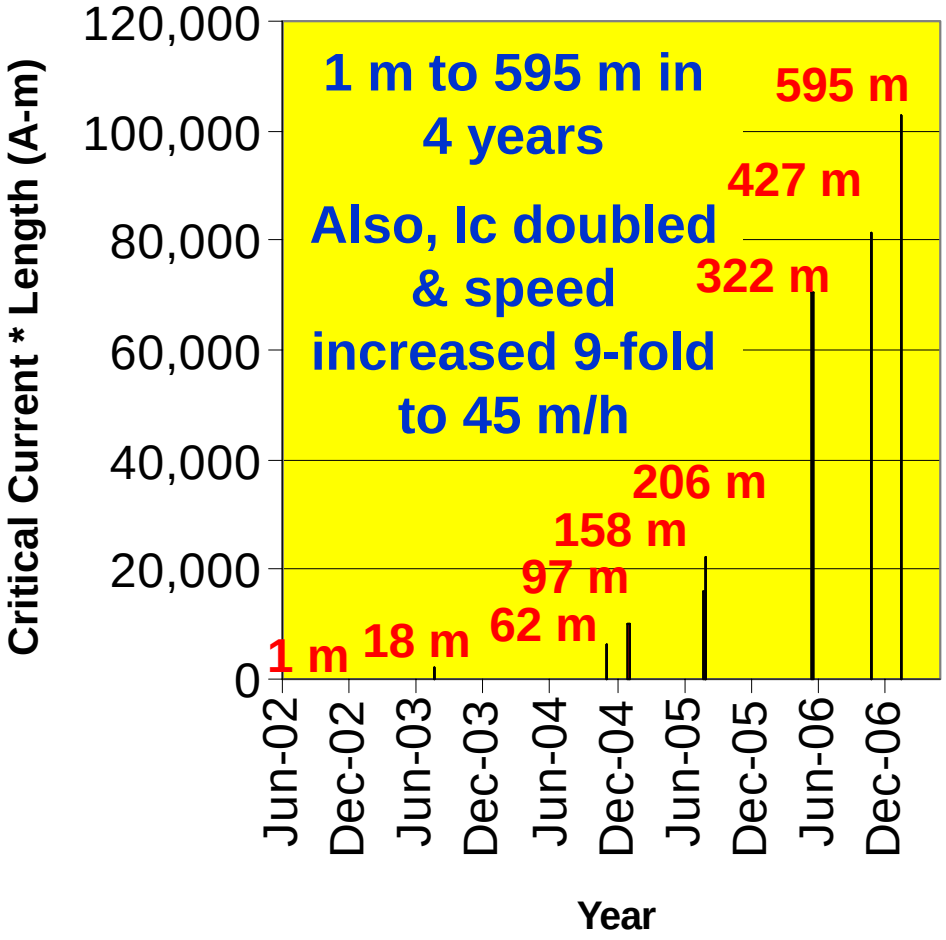
Minimum Ic = 173 A/cm over 595 m

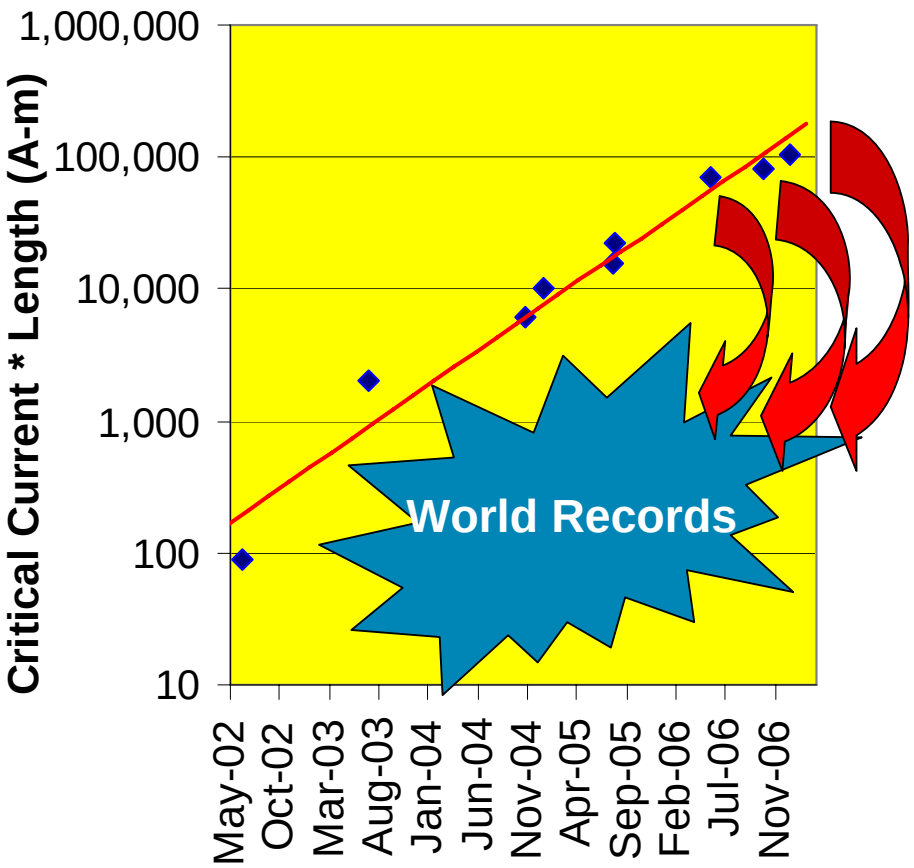
Ic × Length = 102,935 A-m

Uniformity over 595 m = 6.4%

Process (single pass)	Speed of 12 mm tape (m/h)
IBAD MgO	120
Homo-epi MgO	71
LMO	120
MOCVD	45

Progress in IBAD-MOCVD-based 2G conductor has been steadily maintained over the last 4 years



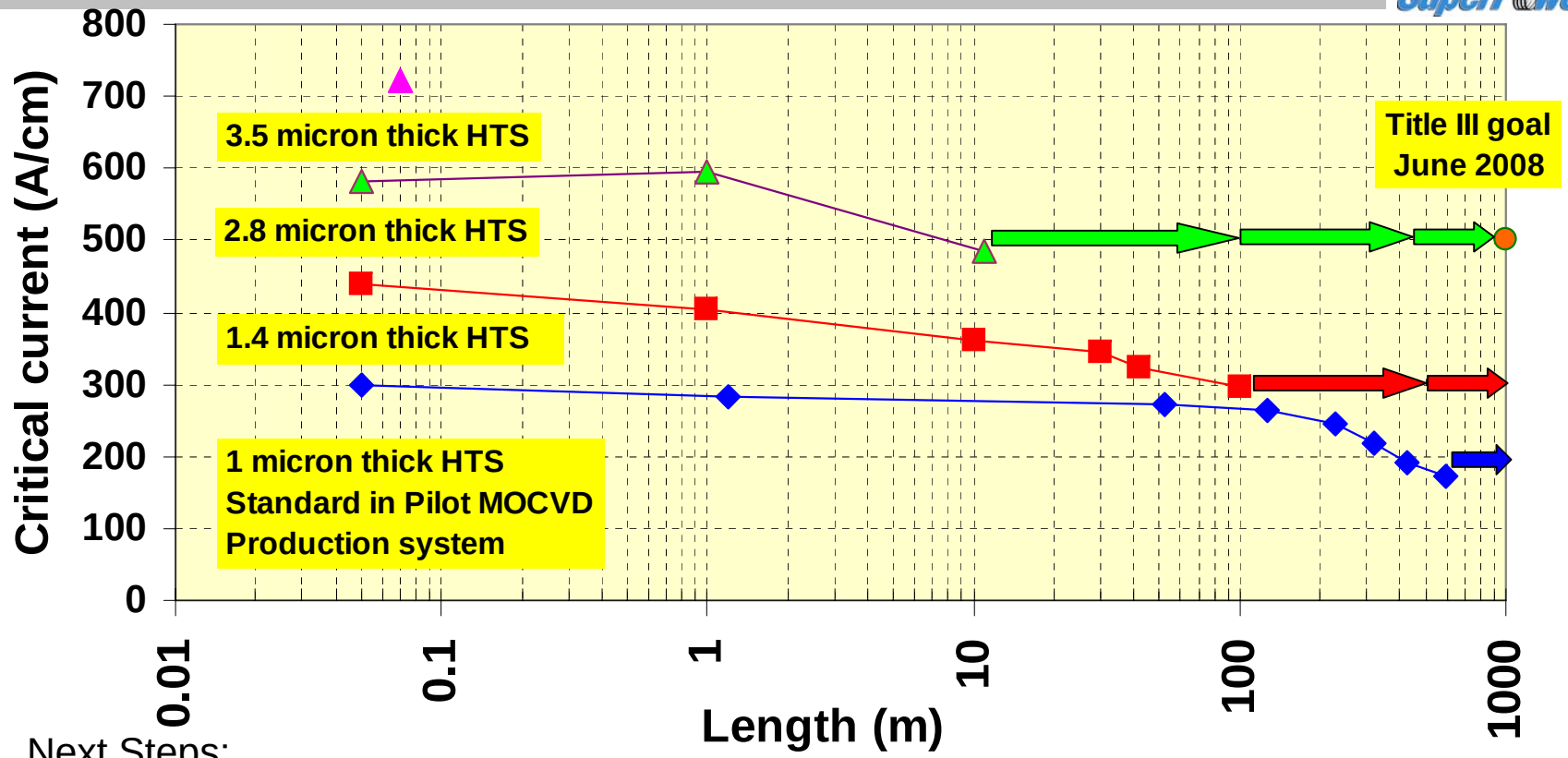


DOE Wire Workshop has consistently been the forum to report achievement of major 2G milestones

- SuperPower first reported crossing 1,000 A-m at 2003 DOE Wire Workshop
- SuperPower first reported crossing 10,000 A-m at 2005 DOE Wire Workshop
- SuperPower first reported crossing 100,000 A-m at 2007 DOE Wire Workshop
- Title III Program goal is to reach 500,000 A-m by June 2008

Cross 1,000,000 A-m by 2009 DOE Wire Workshop ?!

Ic vs Length summary shows progress being made both in Pilot Manufacturing of long lengths & technology development with shorter lengths



Next Steps:

Manufacturing scale up to reach 1000 m with Ic > 200 A/cm

Manufacturing improvements to raise Ic level of 500+m Production lengths to that of short lengths of same film thickness i.e. 500 m and then 1000 m with Ic > 300 A/cm

Technology transition of higher-current conductors to Pilot manufacturing i.e. 100 m, then 500 m and then 1000 m with Ic of 500 A/cm

Substantial improvements made in Ic & speed, & piece lengths of 2G conductors *since Peer Review*

Attribute	2005	Aug 2006 (Peer Review)	Jan. 2007	Improvement after Aug 06
Ic (A/cm) – short, reel-to-reel processed	407	557	**721**	30%
Ic (A/cm) over 1 m	236	470	**595**	27%
Ic (A/cm) over 10 m	215	276	**484**	75%
IBAD speed* (m/h)	1	65	**120**	85%
Buffer speed* (m/h)	n/a	40	**95 to 120**	140 to 200%
MOCVD speed* (m/h)	5	30	**45**	50%
Ic over 200 m at stated speed	106	246	**227**	**Same Ic level with 50 – 100% higher speeds in all processes**
Ic × L (A-m)	22,000	70,520	**102,935**	46%

Rapid progress with higher currents, higher speeds, and longer lengths are all leading the way to a lower-cost 2G conductor

*12 mm wide tape, single pass

2G conductor now available in long lengths with excellent properties for prototype demonstrations

- Piece Lengths ~ 600 m
- Critical Current: 80 – 110 A in 4 mm widths
- Critical current uniformity: ~ 5% standard deviation
- Excellent joints, splices & solderability:
  - No degradation in Ic even when joint/splice was bend over 1" diameter and thermal cycled.
  - Joint/splice resistance ~ 40 nohmcm^2.
  - No problem with soldering to our 2G conductor

Deliveries of kilometers within 4 weeks

2G Wire Price is dropping rapidly!

Longer piece lengths, Higher throughput, Higher Ic,

Higher yield, Lower raw material cost

– all in the last few months have resulted in lower 2G production cost

SCS4050	$ /m	Ic (A) 4 mm wide 77 K, self field	$/kA-m
2006	100	80	1250
2007	65	100	650

4 mm wide with copper stabilizer

SF12050	$ /m	Ic (A) 12 mm wide 77 K, self field	$/kA-m
2006	150	240	625
2007	90	300	300

12 mm wide without copper stabilizer

In addition to all other benefits over 1G, 2G can be cost-competitive with 1G by the end of 2008