An Effort-Minimized Logic BIST Implementation Method

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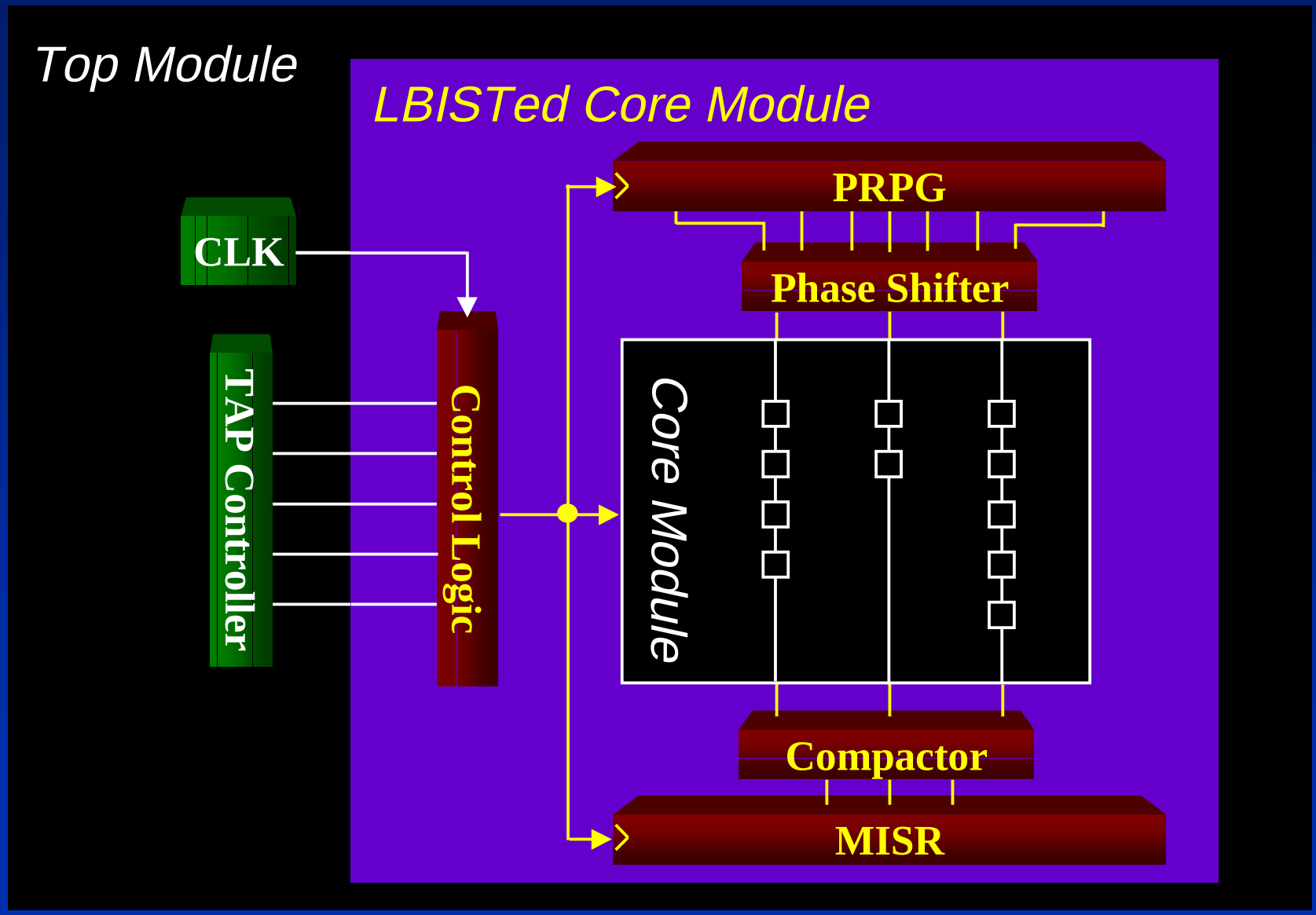
Purpose

- Reduce system test and diagnosis cost
- Reduce the usage of expensive testers by:
  - Reducing tester I/O requirement
  - Reducing tester memory requirement
  - Reducing tester usage time
- Improve test quality by performing at–speed test
- Achieve >95% coverage with LBIST and top–up with ATPG

Outline

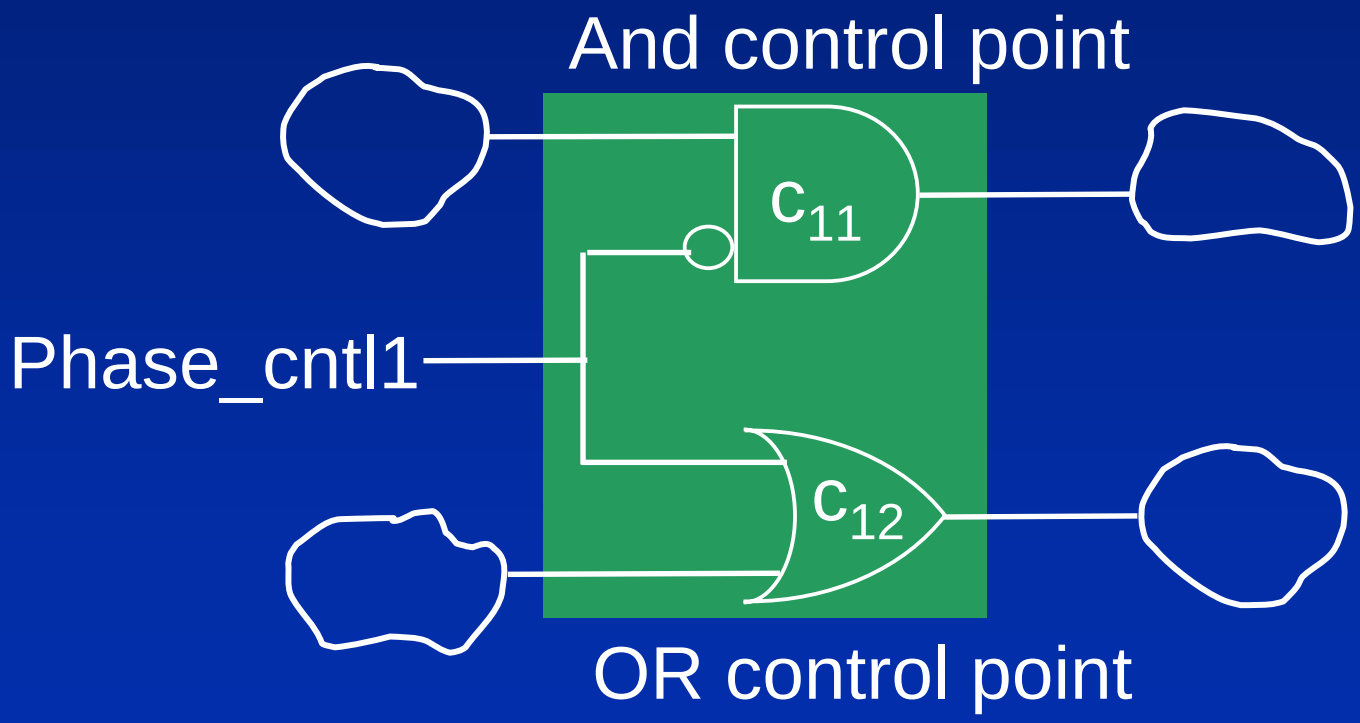
- LBIST general
- Problem specification
- Constrained LBIST insertion
- A design case

LBIST General – Architecture



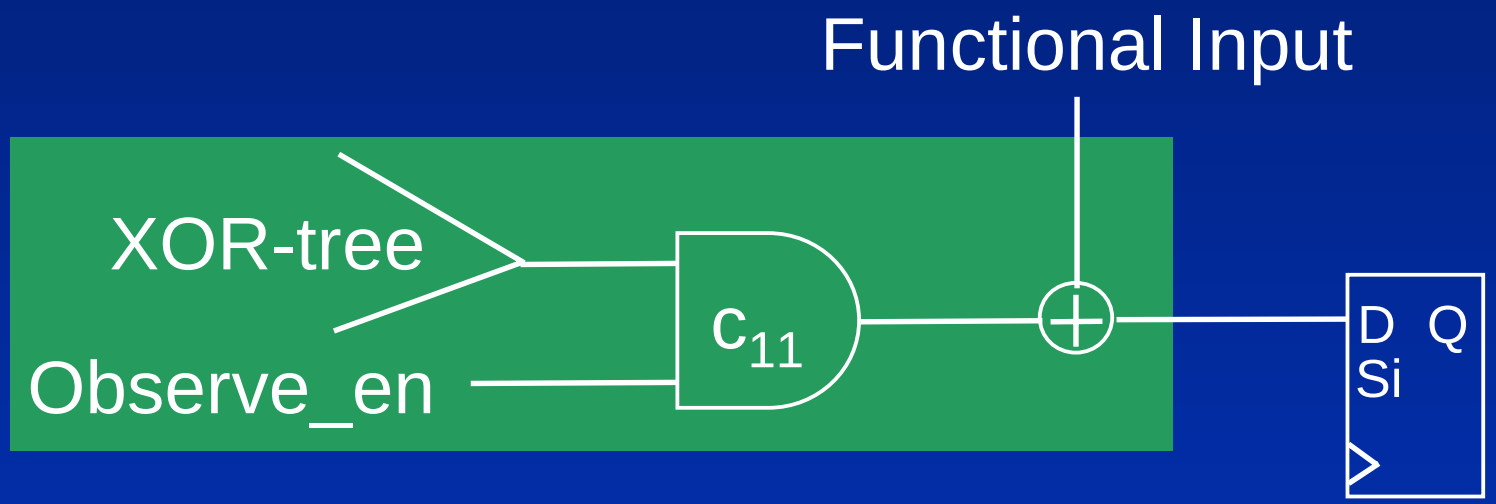
LBIST General – Control Points

- To increase controllability



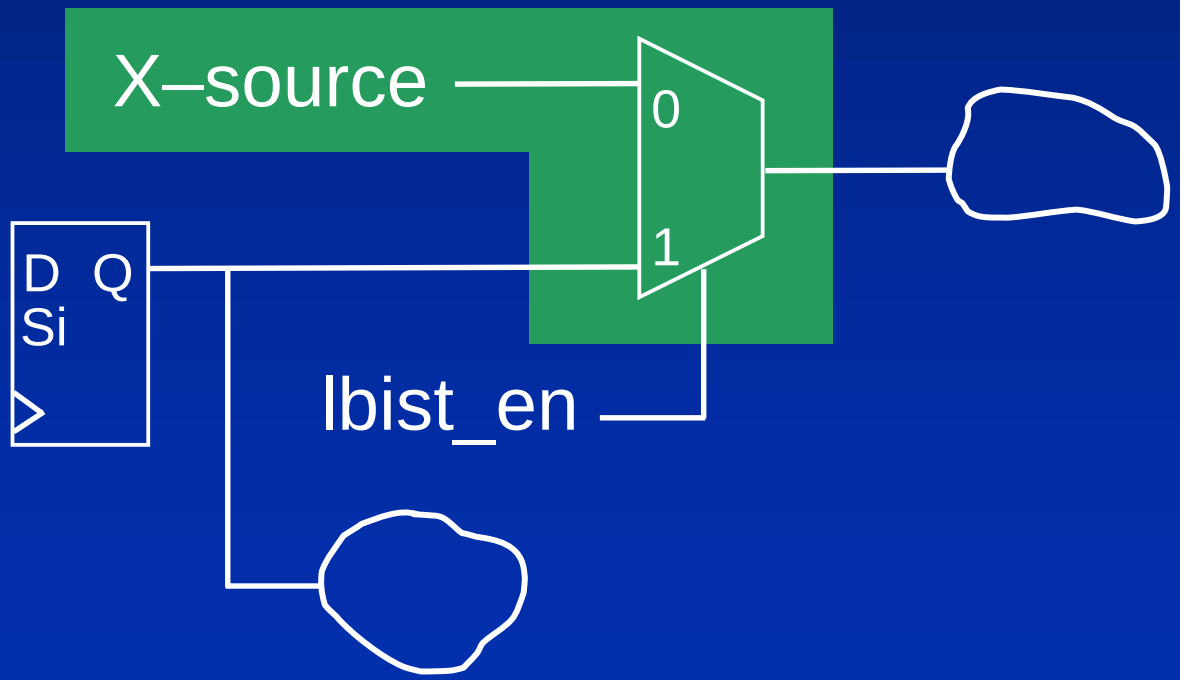
LBIST General – Observe Points

- To increase observability



LBIST General – X Boundings

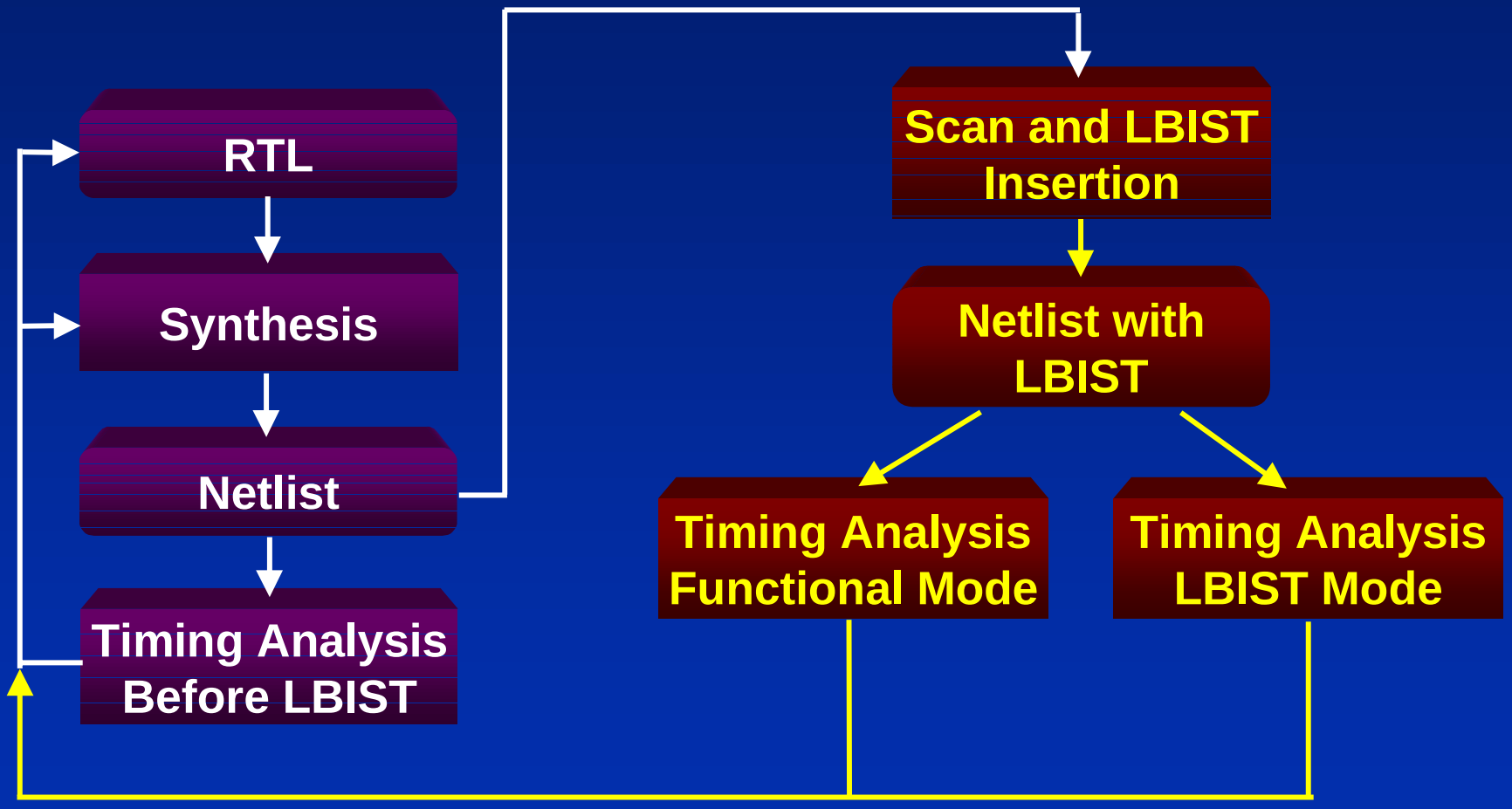
- X–bounding logic to prevent x–propagation to a MISR



LBIST General – X Boundings (cont)

- Types of x–sources:
  - Uncontrolled primary inputs
  - Floating nets
  - Non–scannable flip–flops
  - Black–boxed memory outputs
  - Buses with potential contention, etc.

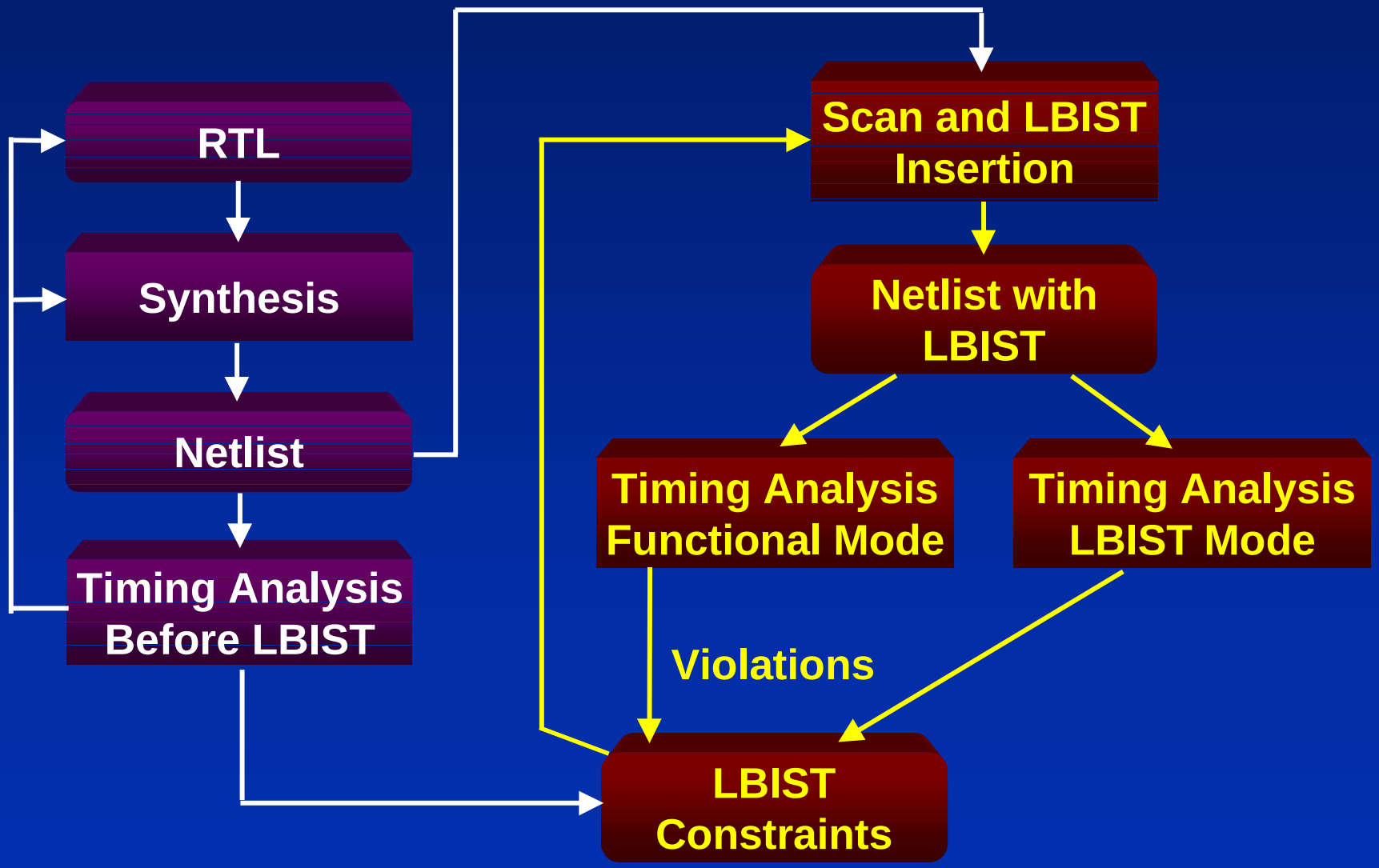
LBIST General – Design Flow



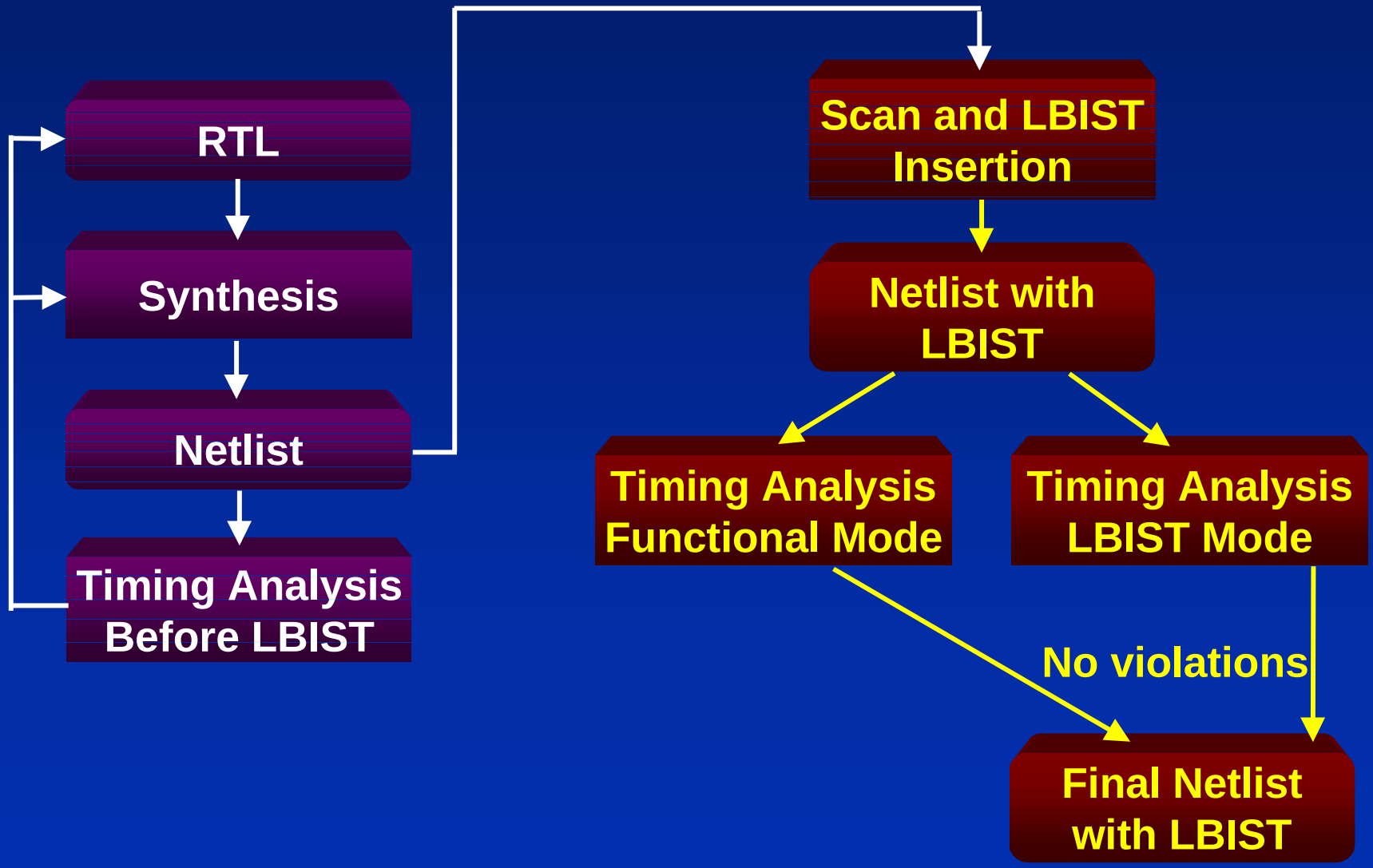
Problem Specification

- New timing violations in functional mode caused by
  - Control points
  - Observe points
  - X–boundings
- Extra timing violations in LBIST mode caused by
  - Multi–cycle paths
  - False–paths

Timing Constrained LBIST – Flow



Timing Constrained LBIST – Flow



Test Point Insertion

- $\mathbf{TP_{ctrl}}$: a set of control points inserted
- $\mathbf{TP_{obs}}$: a set of observe points inserted
- $\mathbf{TP_{xbnd}}$: a set of x–boundings inserted

Timing Analysis

- $\mathbf{P_{func}}$: a set of timing violation paths before LBIST
- $\mathbf{P_{lbist}}$: a set of timing violation paths after LBIST in functional mode
- $\mathbf{P_{false}}$: a set of timing violation paths after LBIST in LBIST mode

Timing Analysis (cont)

- ($\mathbf{P_{lbist} - P_{func}}$) : a set of timing violation paths in functional mode caused by LBIST
- ($\mathbf{P_{false} - P_{lbist}}$) : a set of timing violation paths in LBIST mode caused by multi–cycle paths or false paths

Timing Violations vs. Test Points

- Timing violation control points – $\mathbf{TP_{ctrl\_vio}}$:

$$\{\ TP \mid (TP \in \mathbf{TP_{ctrl}}) \wedge (\exists P \in (\mathbf{P_{lbist}} - \mathbf{P_{func}}): TP \in P)\ \}$$

- Timing violation observe points – $\mathbf{TP_{obs\_vio}}$:

$$\{\ TP \mid (TP \in \mathbf{TP_{obs}}) \wedge (\exists P \in (\mathbf{P_{lbist}} - \mathbf{P_{func}}): TP \in P)\ \}$$

- Timing violation x-boundings – $\mathbf{TP_{xbnd\_vio}}$:

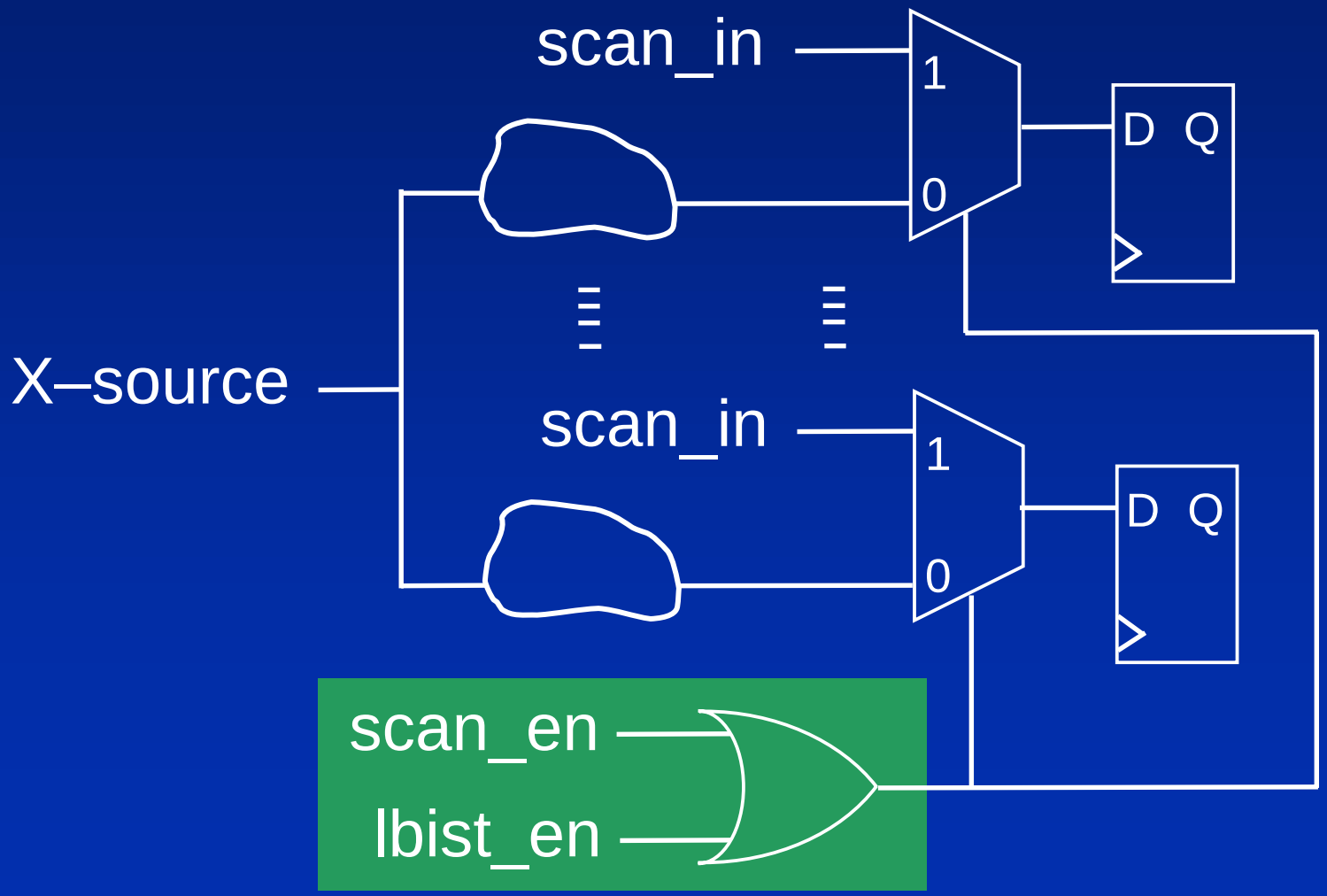
$$\{\ TP \mid (TP \in \mathbf{TP_{xbnd}}) \wedge (\exists P \in (\mathbf{P_{lbist}} - \mathbf{P_{func}}): TP \in P)\ \}$$

Constrained LBIST Insertion

- New control points: $\mathbf{TP_{ctrl} - TP_{ctrl\_vio}}$
- New observe points: $\mathbf{TP_{obs} - TP_{obs\_vio}}$
- New x–boundings: $\mathbf{TP_{xbnd} - TP_{xbnd\_vio}}$
  - For each x–bounding in $\mathbf{TP_{xbnd\_vio}}$, disable the capture of “x” into scan FFs

Constrained LBIST Insertion (cont)

- Disable receiving FFs from capturing x



Constrained LBIST Insertion (cont)

- ($\mathbf{P_{false}} - \mathbf{P_{lbist}}$) : timing violations in multi–cycle paths or false paths
  - Disable receiving FFs from capture

A Design Case

- LBIST and ATPG Comparison

	Initial LBIST	ATPG
Chains	200	10
Chain Length	321	6,852
Vectors	8,192	5,924
Coverage (%)	96.43	97.79
Test Cycles	2.6 M	40.6 M
Test Time (ms)	42	1,624

A Design Case (cont)

- Initial and Constrained LBIST Comparison

	Initial LBIST	Constr. LBIST
Control points	993	967
X-bound points	712	711
Observe points	1,000	1,000
Vectors	8,192	8,192
Coverage (%)	96.43	95.43

Conclusion

- Reduce manufacturing costs and ease system diagnosis by using LBIST
- Minimize LBIST design efforts by applying constrained LBIST technique
- Target 95% fault coverage with LBIST
- Prove the value of this technique on large industry designs