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비즈니스 및 IT 리더를 위한 최고의 컨퍼런스

지능형 실시간 제조 환경 통합관리 시스템 구축 방안 및 사례
– WebSphere Real Time 기반

노주환 박사
나무 아이앤씨(I&C)

Discover. Interact. Optimize.

What's Real Time Specification for Java?

"Game Changers"

"JAVA at its Fastest"

"Java For Embedded Systems"

"It's for Automation and Controls"

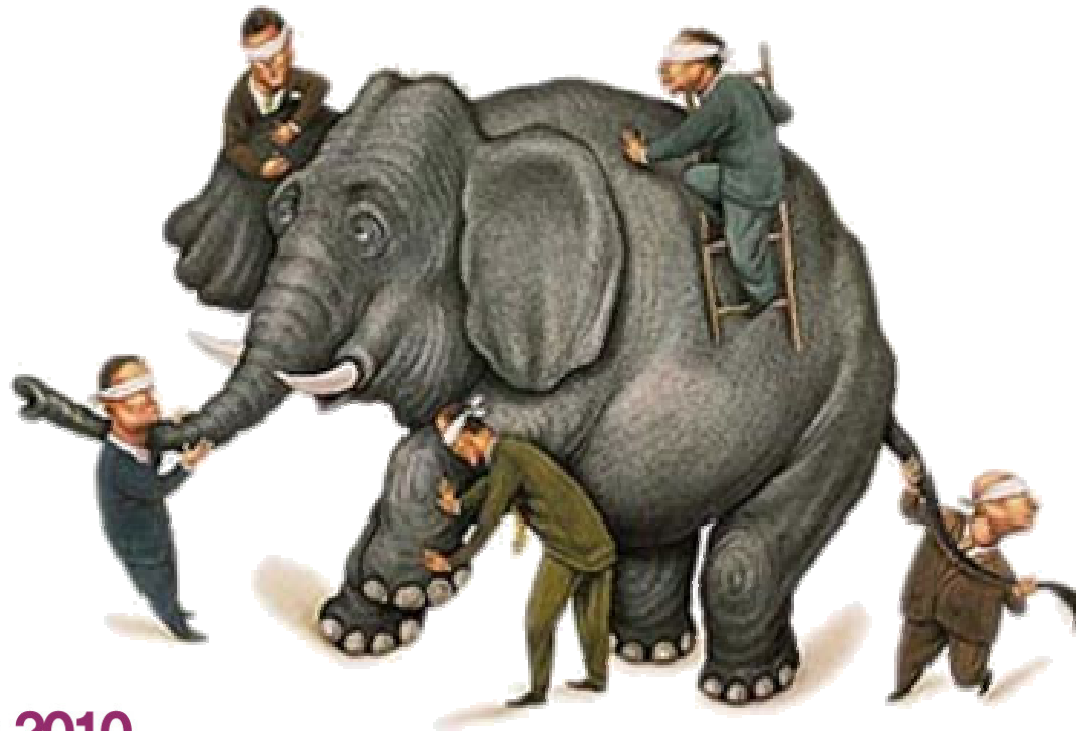Impact Korea 2010
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Then, What does Real Time mean?

Real Time is <u>NOT</u> the same as real fast!

Efficiency & Throughput is important,
but predictability is essential!

To Use Technical Terms…

Temporal Correctness Condition(TCC) of S/W

Real-Time == Determinism == Predictability

Typical TCC : Deadline, Latency, Jitter

Hard Real Time Requirement

Soft Real Time Requirement

Non Real Time Requirement

So What?

Who Cares?

What's in it for ME?

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How is the Real Time System implemented?

- Most of the Real Time/embedded systems are
  - developed in C / C++
  - C/C++ is more productive than assembly code
  - <u>NOT</u> the most productive, error-free languages

- Increasingly difficult to find C/C++ programmers or to retain them

- Starting to struggle with the maintenance costs of C/C++ applications

Any NEW approaches?

Industry needs a common, high-level, fully supported, correct, advanced (Java-based) Real Time application development platform.

Lo and behold!

- A business advantage over C, C++, Ada
  - Robust language: designed to catch many errors at compile time
  - Object Oriented ~~...~~ ssibility, intrinsic information
  - Safe ~~...~~ tion Fault or S
  - Co
  - A

Java - H
     hi

Wait, Java is Stochastic!

- Java is **unsuitable** for developing Real Time systems
  - Java is Slow (Hmmm…)
  - Non-deterministic GC (Stop the World!)
  - JIT Compilation – Dynamic Class Loading
  - Inconsistent Memory Allocation
- Java Language Shortcomings
  - Java thread scheduling is purposely under-specified
    (to allow easy implementation of JVM on as many platform)
  - Java provides coarse grained control over memory allocation,
    and it does not provide stack memory
  - Java does not provide high resolution time, nor access to signals,
    e.g. POSIX Signals

RTSJ Mission Statement

[To extend] *The Java Language Specification and The Java Virtual Machine Specification*

[to provide] an Application Programming interface that will enable the creation, verification, analysis, execution, and management of Java threads whose correctness conditions include timeliness constraints (also known as Real Time threads)

RTSJ: Chronology of the Specifications

1998

Real Time Specification for Java (JSR-001) proposal submitted

Many companies represented : IBM, Sun, Ajile, Apogee, Motorola, Nortel, QNX, Thales, TimeSys, WindRiver

2002

JSR-001 approved by the Java Community Process

TimeSys Reference Implementation

2005

RTSJ update proposal submitted (JSR-282)

-Several JSR-1 compliant products (Apogee, IBM, Sun)
-RTGC Available in IBM's JVM

2007

RTGC added to Sun's JSR1-compliant JVM

JSR-1 APIs added to RTGC enhanced JVMs

NEW JSRs

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RTSJ: Key Features

- Thread Scheduling & Dispatching
  - Priority-preemptive scheduling
- Enhanced Synchronization
  - Priority inversion avoidance
- New Memory Management
  - Allocation contexts without garbage collection
- Added Asynchronous Event Processing
  - Internal events, external "happenings", and handlers
- Time, Clocks and Timers
- Real Time GC

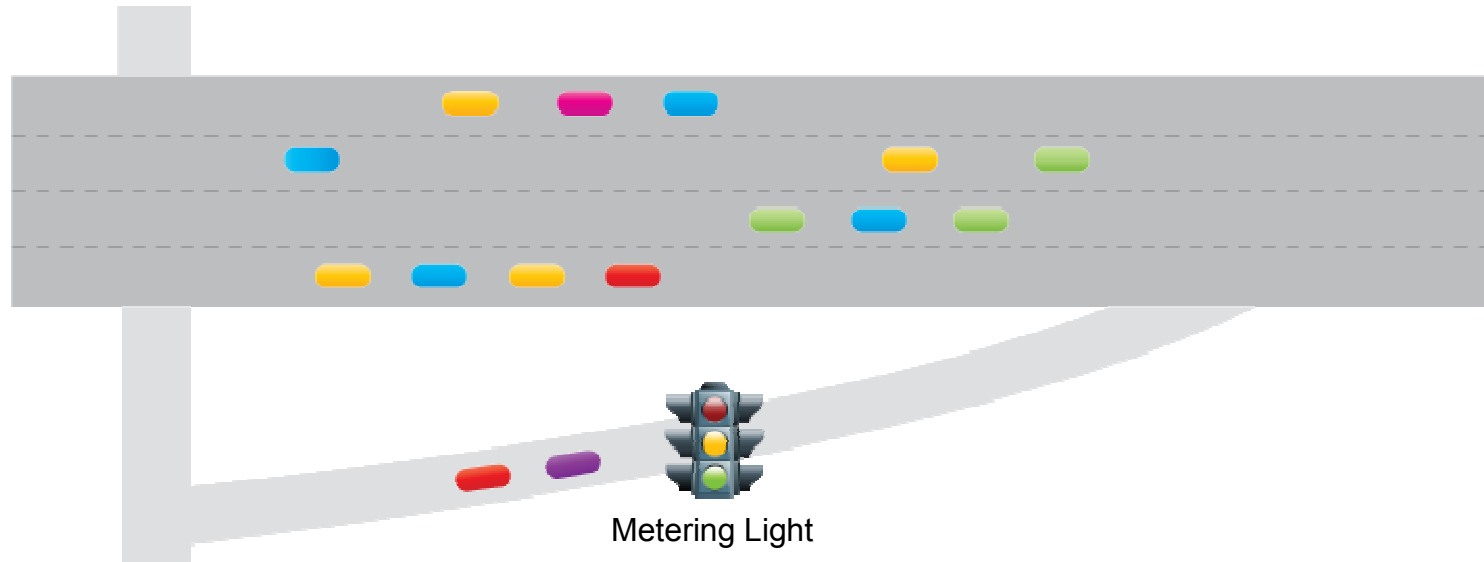*Satisfies most of the RT-POSIX requirements*

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RTSJ Analogy: Conventional Systems

Metering Light

- 고속도로는 Metering light을 이용하여 교통량 – throughput – 관리
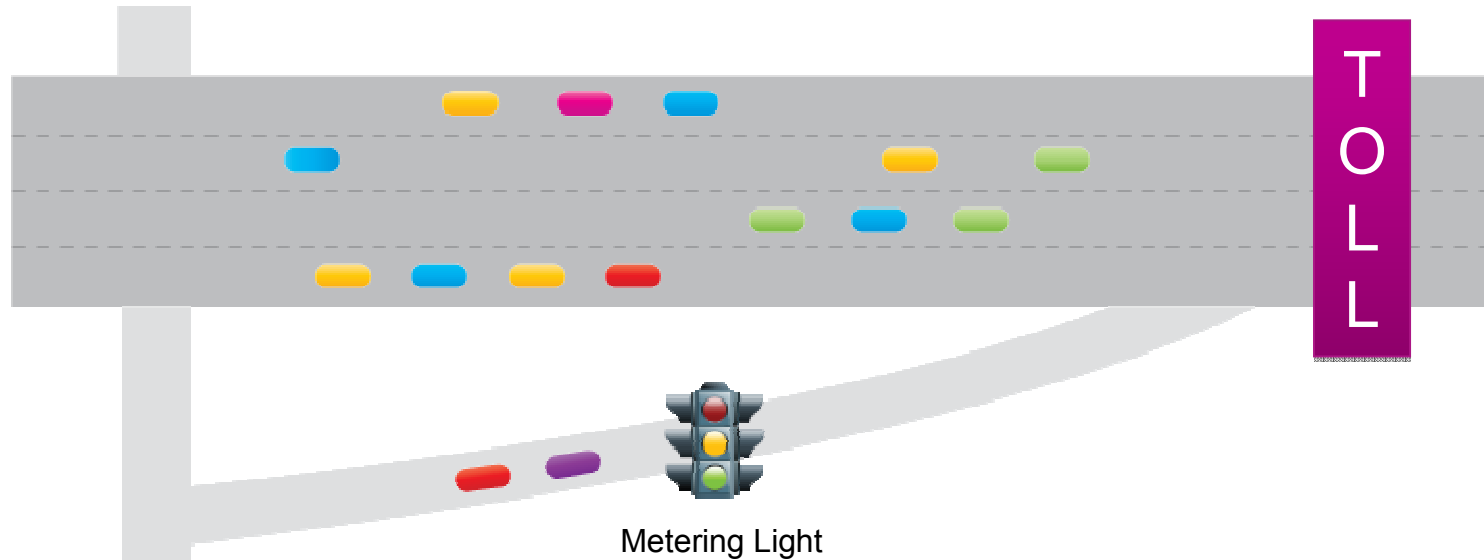- 많은 컴퓨터 시스템들은 유사한 방법을 사용하여 서버의 load를 최소화함으로써 Throughput 최적화

RTSJ Analogy: Garbage Collection

Metering Light

Java는 고속도로의 각 차선을 명확히 구분하고 노면관리를 (편리한 개발플랫폼과 생산성제고 환경) 제공하지만 모든 사람들이 반드시 거쳐야 하는 Toll gate (Garbage Collection)가 있고 여기서 비용을 지급하기 위해 대기해야 하는 단점이 있다.

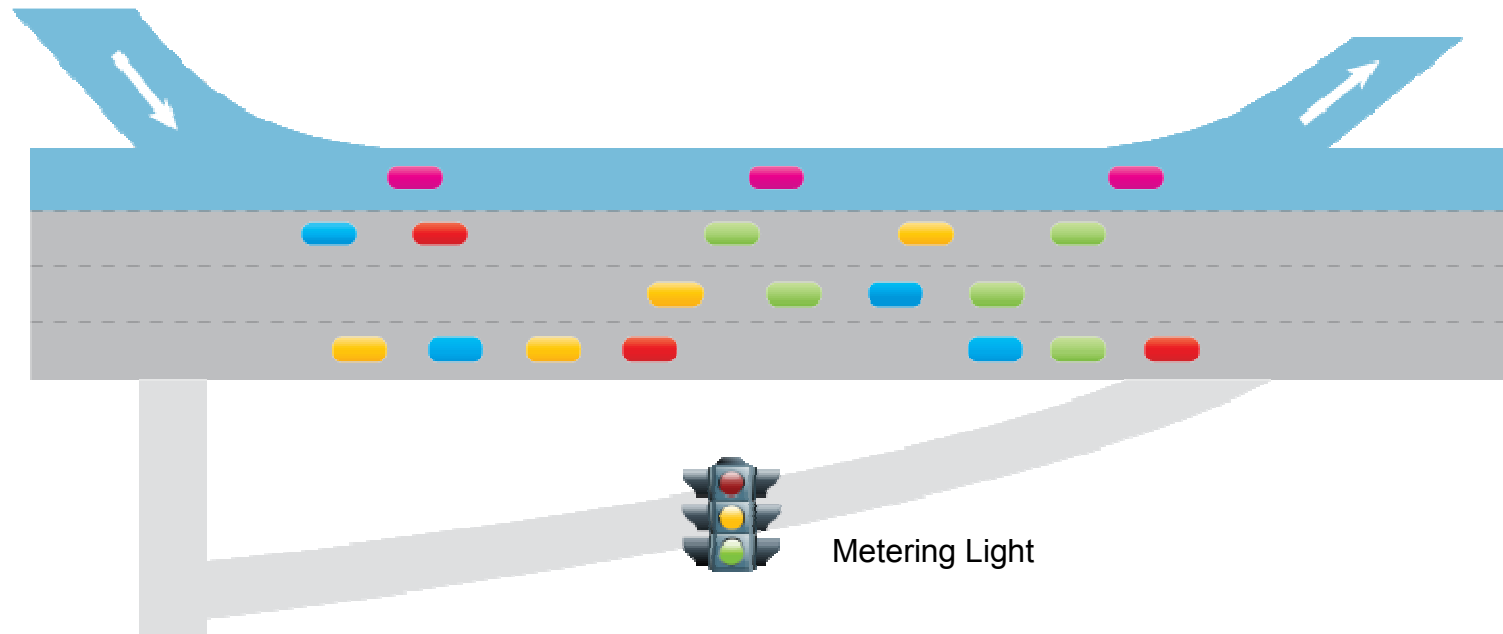# RTSJ Analogy: Real Time Threads

Real Time Threads는 버스 전용 차선에 비유될 수 (Metering Light에서 대기도 줄어드는) 있고 이를 통해 좀 더 빠르고 편안하게 목적지에 도달하는 것과 같다

Metering Light

그러나 버스 전용 차선도 다른 버스(Threads)와 공유하게 되므로 결국 정체와 지체가 발생하기도 한다 (현실과 달리 RTSJ에서는 버스전용 차선에 Toll gate을 두기도 하고 아예 제거하는 것도 가능)

RTSJ Analogy: NoHeap RealTime Threads
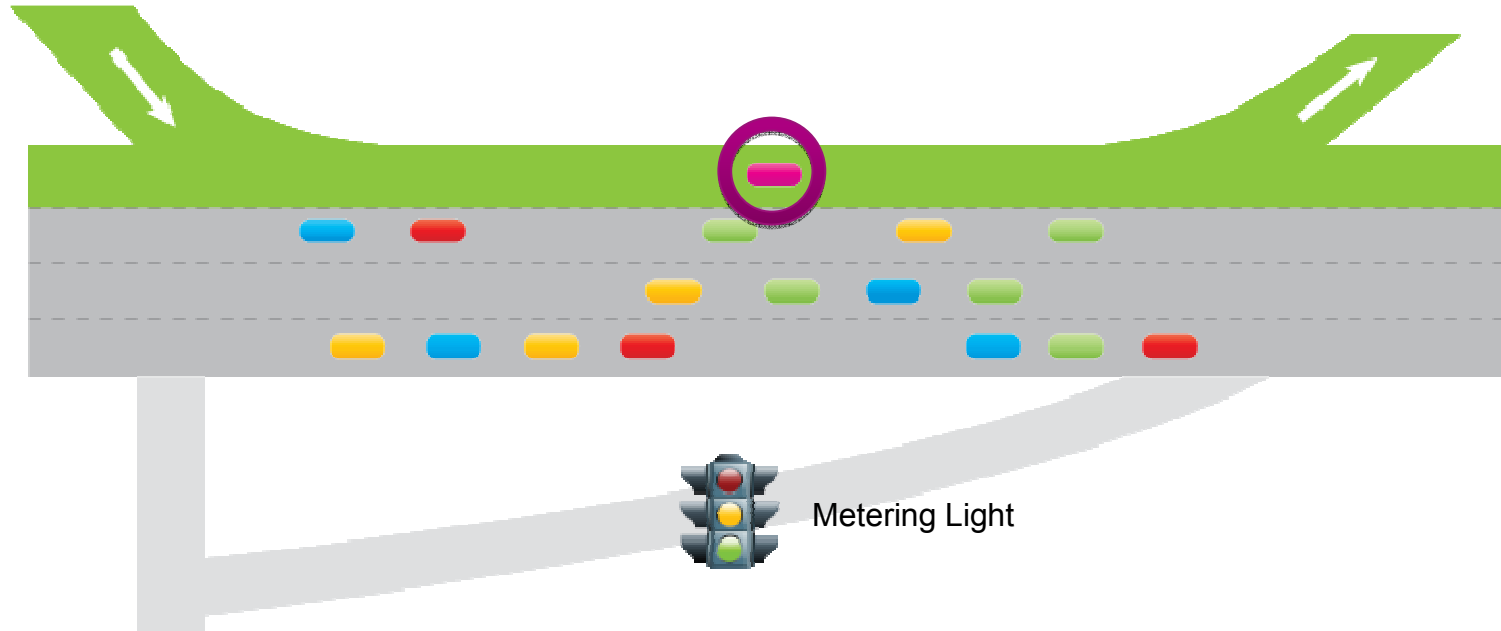
No-Heap Real Time Threads는 Toll gate는 존재하지도 않는 나만의
개인전용 차선으로 여기서는 지체나 정체 걱정이 없다

Metering Light

RTSJ는 단일 시스템 내에서 NHRT, RTT, java.lang.Threads 를 모두 사용할 수
있도록 지원한다
주의: 여전히 고속도로(시스템)가 효과적으로 수용할 수 있는 자동차 수에는
그 한계가 있다

RTSJ: Memory Model

- Java Heap
- *Non Real Time*
  - Regular Java threads
  - Maximized throughput

Take-away:
Real Time & regular Java code는 메모리, state 등 run-time환경정보를 공유하며 이는 이전의 RT 환경에서는 불가능했던 것

Data Transfer queues
Immortal Memory

- RTSJ Scoped Memory
- *Soft Real Time*
  - Realtime Threads
  - RTGC

- RTSJ Immortal Memory
- *Hard Real Time*
  - NoHeapRealtime Threads
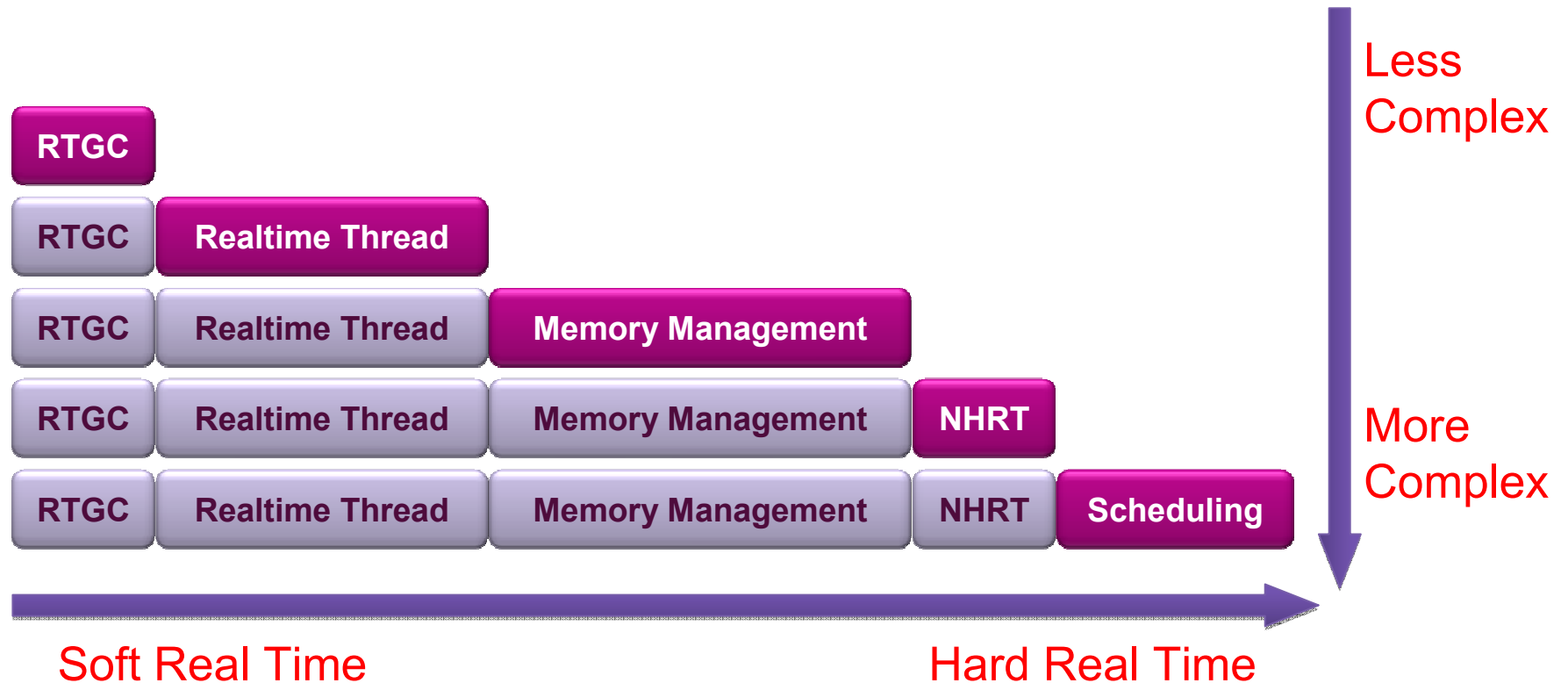 - Bounded jitter

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RTSJ : Deployment in the Real Life

Remember, there is no such thing a free lunch
and designer should consider trade-off!

Less Complex

More Complex

RTGC				
RTGC	Realtime Thread			
RTGC	Realtime Thread	Memory Management		
RTGC	Realtime Thread	Memory Management	NHRT	
RTGC	Realtime Thread	Memory Management	NHRT	Scheduling

Soft Real Time

Hard Real Time

*So, how "deterministic" is
Real Time Java anyway?*

RTSJ: Lab Tests

Non Real Time GC

Periodic Latencies

Running n RTT thread, 2 GP threads, SerialGC

Period: 20000000 ns
Running time: 200 secs

Java RTS2.1, RTT/Serial GC/2GP on Solaris/quad-core 2.8Ghz Opteron
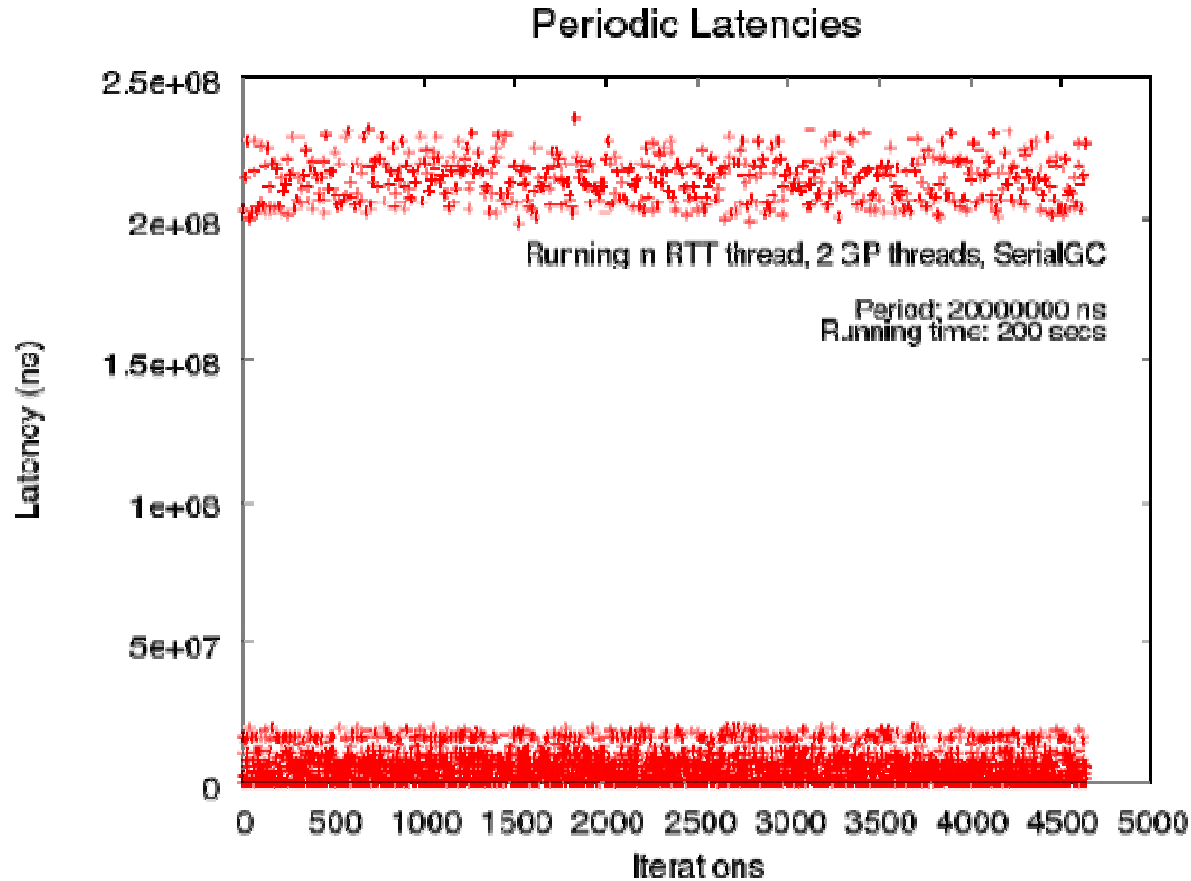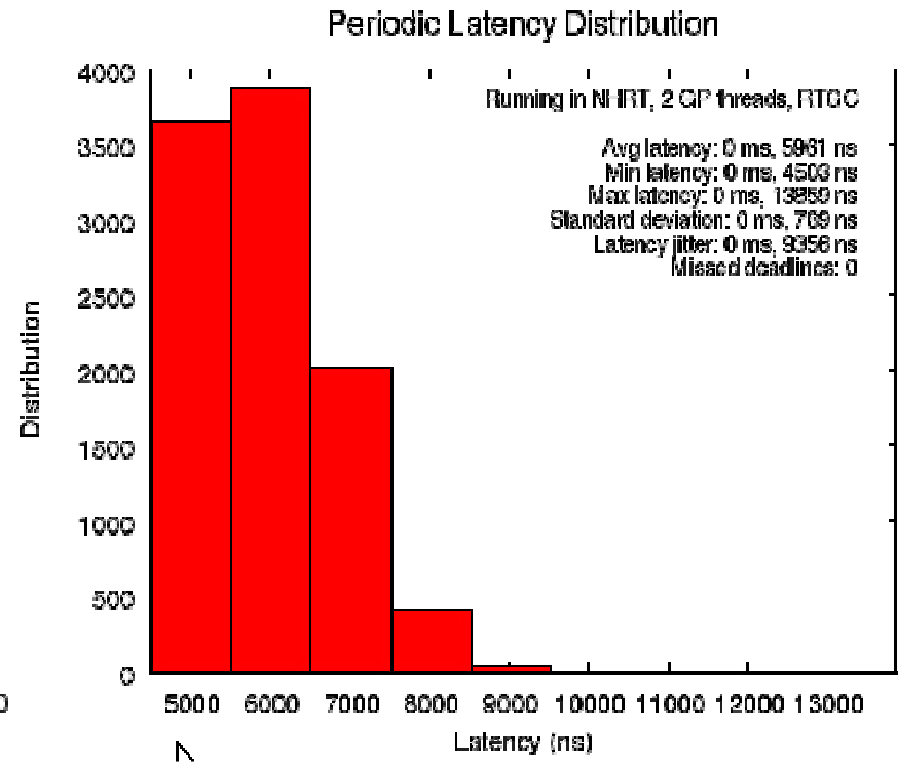
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RTSJ: Lab Tests

Real Time GC

Java RTS2.1, RTT/Serial GC/2GP on Solaris/quad-core 2.8Ghz Opteron

Courtesy: SUN

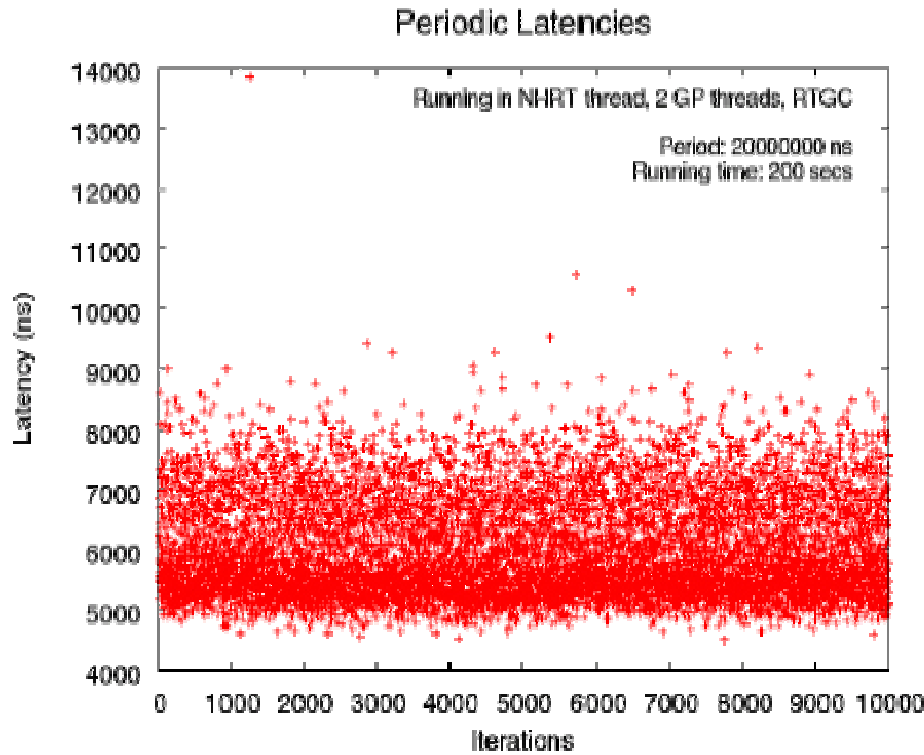# RTSJ : Real World – SIP Server

- Carrier-grade blades (HS21XM) running WVE/ND/WAS/WRT with a client-provided tests
- Using the SIP server that is part of the IBM WebSphere stack
- Real Time Concurrent/Incremental GC
- NO AOT*

*Ahead Of Time Compile

RTSJ : Real World – SIP Server

Real System running with Generational GC

Peer A

Peer B

Packets sent

ack

Time passes, Garbage Collects

GC Occurs,
Processing Stops

Peer A

Network Storm : packets get backed up

Peer B

No acknowledgement, packets Retransmitted
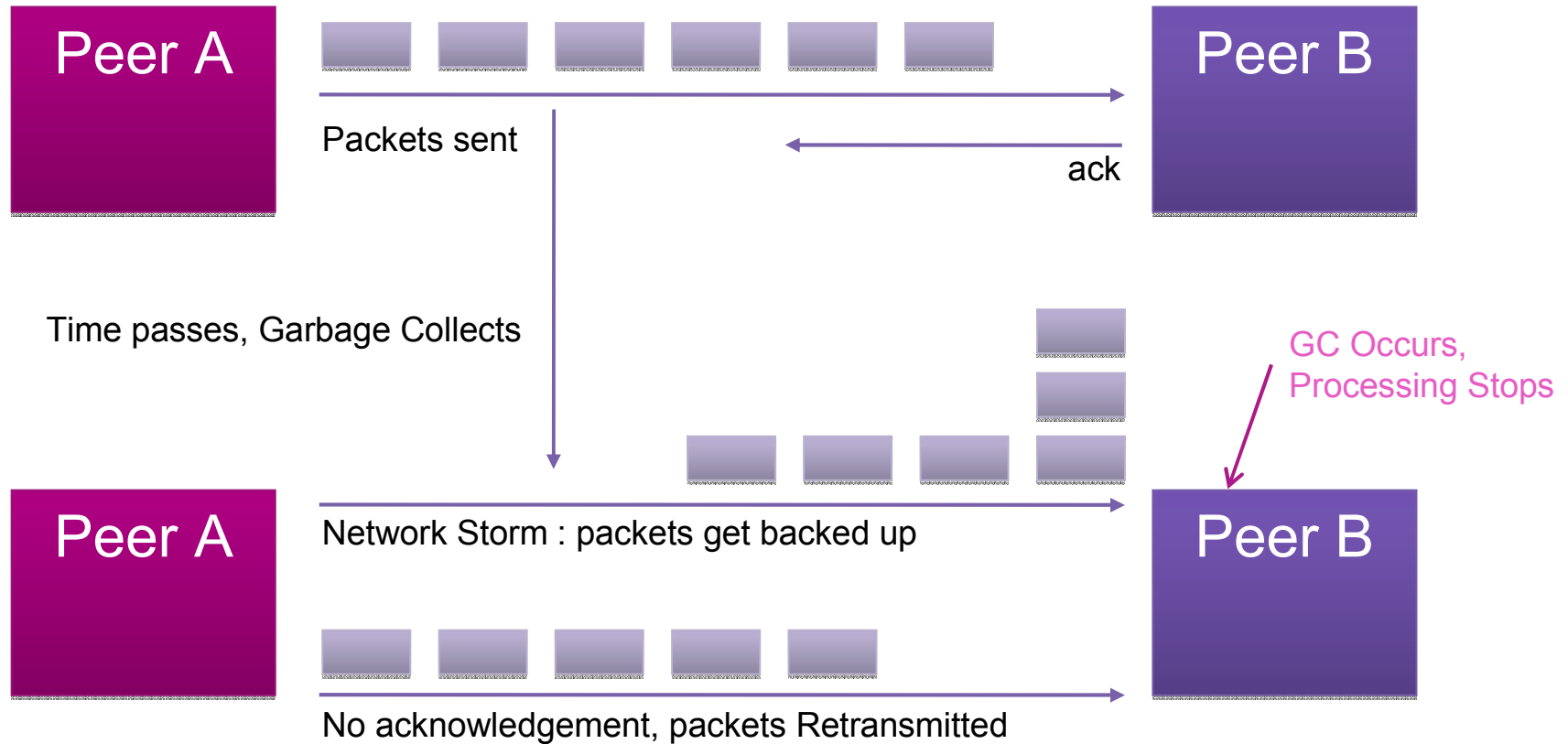
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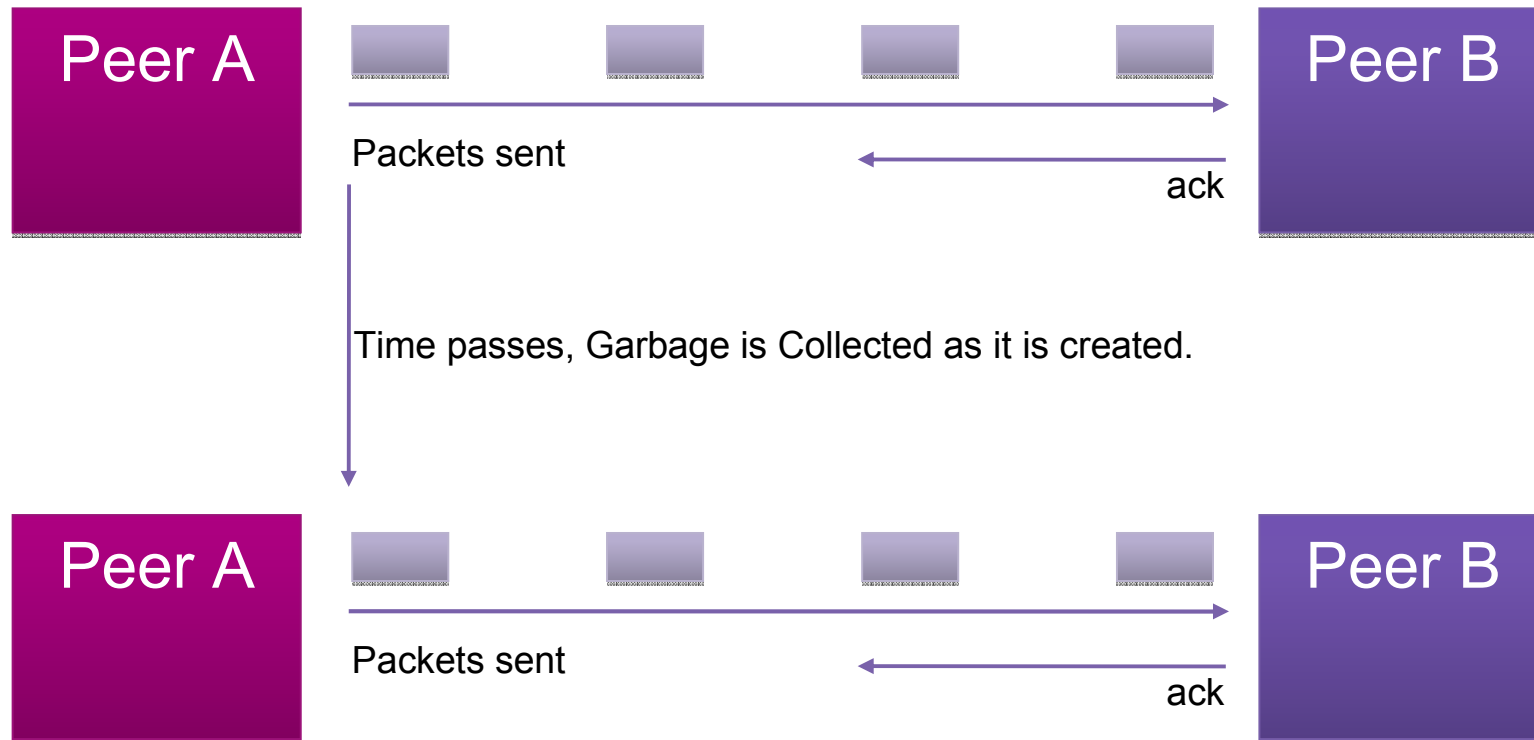
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RTSJ : Real World – SIP Server

Real System running with Real Time Incremental GC

Peer A   Peer B

Packets sent

ack

Time passes, Garbage is Collected as it is created.

Peer A   Peer B

Packets sent

ack

RTSJ : Real World – SIP Server

Real SIP Server Performance Results
Generational GC vs. Real Time Incremental GC

Call Latency
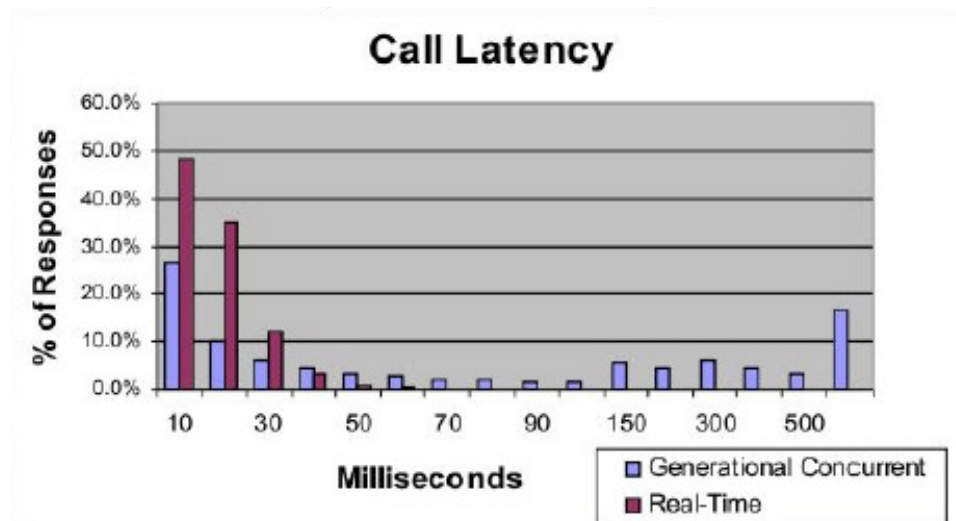
Throughput:
Real Time < Generational

Maximum Latencies:
Real Time: < 100ms
Generational: < 1000ms(1s)

Latencies greater than 50ms:
Real Time: 0.3%
Generational : 50%

✓ Findings:
- Real Time(Incremental) GC has slightly less throughput than Generational. However, 98% reduction in standard deviation of GC pause times
- Reduced pause times results in reduced latencies

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Smarter NongShim – Real Time Visibility

Real Time CTQ & Cost Management

Empower Operators! (Paperless)　　　　Plant floor has all the answers!

Silo	Mixer, Roller	Steamer, Fryer, Cooler	Weight Checker
	?	?	
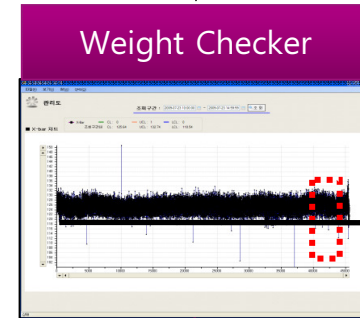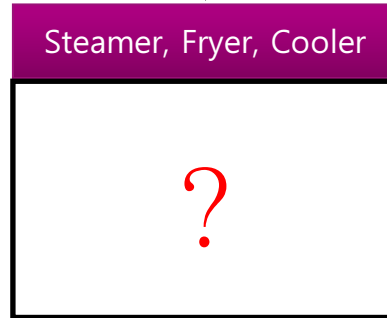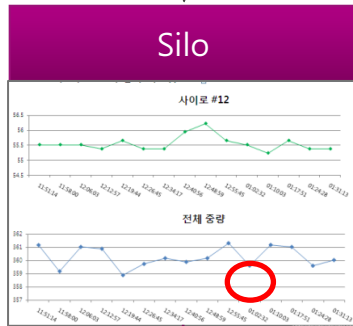
Non-invasive, Real Time, Horizontal
Data Acquisition for IT Systems Required
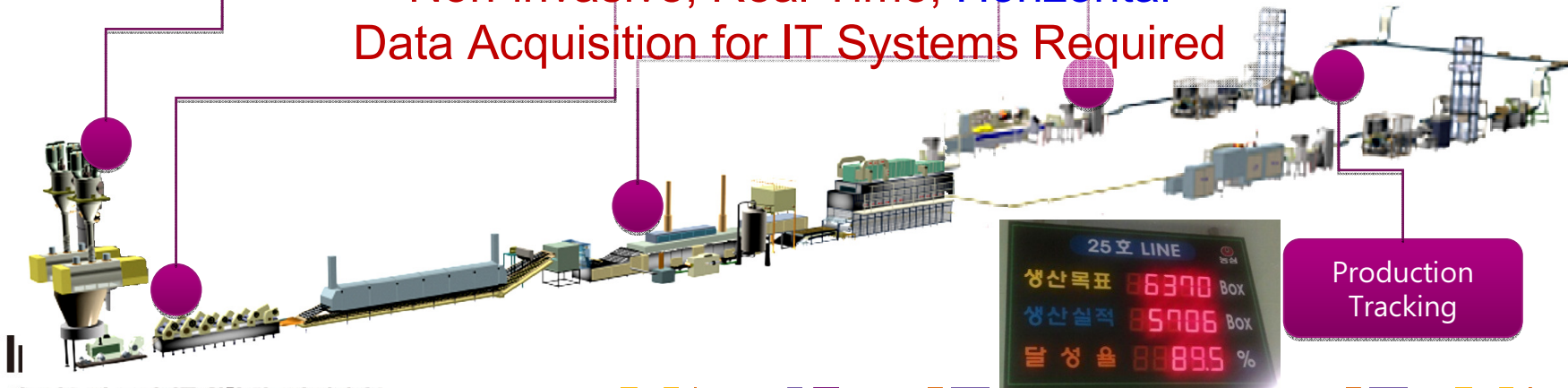
Production Tracking

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Smarter NongShim – Values Delivered

Before

Equipment Display → **Defect Identification** → **Data Collected**

Data Processed

| 구 분(g)	계	구 분	계
110	813	126	293971
111	8	127	268938
112	10	128	197870
113	14	129	116211
114	43	130	53962
115	59	131	20838
116	172	132	6850
117	328	133	2245
118	881	134	792
119	2427	135	324
120	7216	136	157
121	20864	137	78
122	53314	138	51
123	110300	139	40
124	187732	140	21
125	260278	총 수량	1606807

Data Collected

```
-*              11
7               0
6               0
5*              3
4               0
3               2
2*              2
1*-----------   3
0************    791
1*****          133
2*              13
3*              7
4*              14
5---------       10
6*              3
7*              2
+*              3
BATCH COUNT -------- 500
INDIVIDUAL CY. ----------1
BATCH PRINT C. ----------1
```

Shift/Daily Reports

생산 호기	신라면멀티(24호)
데이터 수(n)	1,606,807
데이터 수집 기간	2009년 4월 01일 06시 00분 ~ 2009년 4월 30일 05시 59분까지
데이터 수집 방법	Auto Recorder
표준편차(σ)	2.2385
불량율 중량초과율(%)	5.31
중량미달율(%)	0.75
규격 상한값(g)	129.00
규격 하한값(g)	121.00
평 균 값(g)	126.0202
시그마 상한 수준(σ)	1.33
시그마 하한 수준(σ)	2.24
정 량 율(%)	93.94

- Well-managed, proven process. However, time-consuming manual process prone to human error resulting in low data reliability.
- Reports to HQ often delayed.
- Difficult, if not infeasible, to use for root cause analysis and multivariate co-relational analysis

After

135g[max]

125g [target weight]

119g[min]

weight ▼

weight ▲

Defect
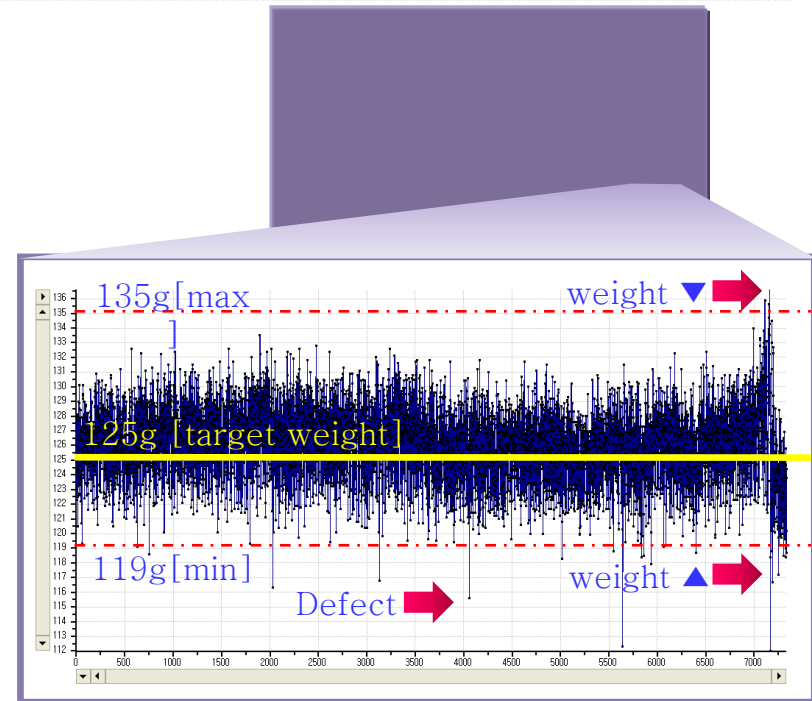
- Paperless, transparent Real Time data acquisition with click-driven analysis/reporting
- Reduced flour scrap (1g/pack is $0.87M/Yr. saving, let alone less CO_2 emission)
- Higher output (99% of the Theoretical Output)
- Up to 200% faster Time-to-Recover

RTSJ References

- Financial Trading/Analytics Systems
  - NASDAQ
  - Very tight time constraints for Real Time data analysis
  - Very fast time to market pushing drive to Java from C
- Network Routers
  - Packet routing – tighter timing typically single-digit ms
- Industrial Devices / Automation
  - From sub-ms (NHRTs) to single-digit ms (standard Java threads)
  - Mitsubishi, Project Blue Wonder (SUN)
  - POSCO Mg. Plant
  - NongShim Gumi Plant

References

- Military & Aerospace Industry
  - BOEING
  - NASA
  - Air Force Research Laboratory
  - DARPA – Autonomous vehicle control
- TELCO & N/W Industry
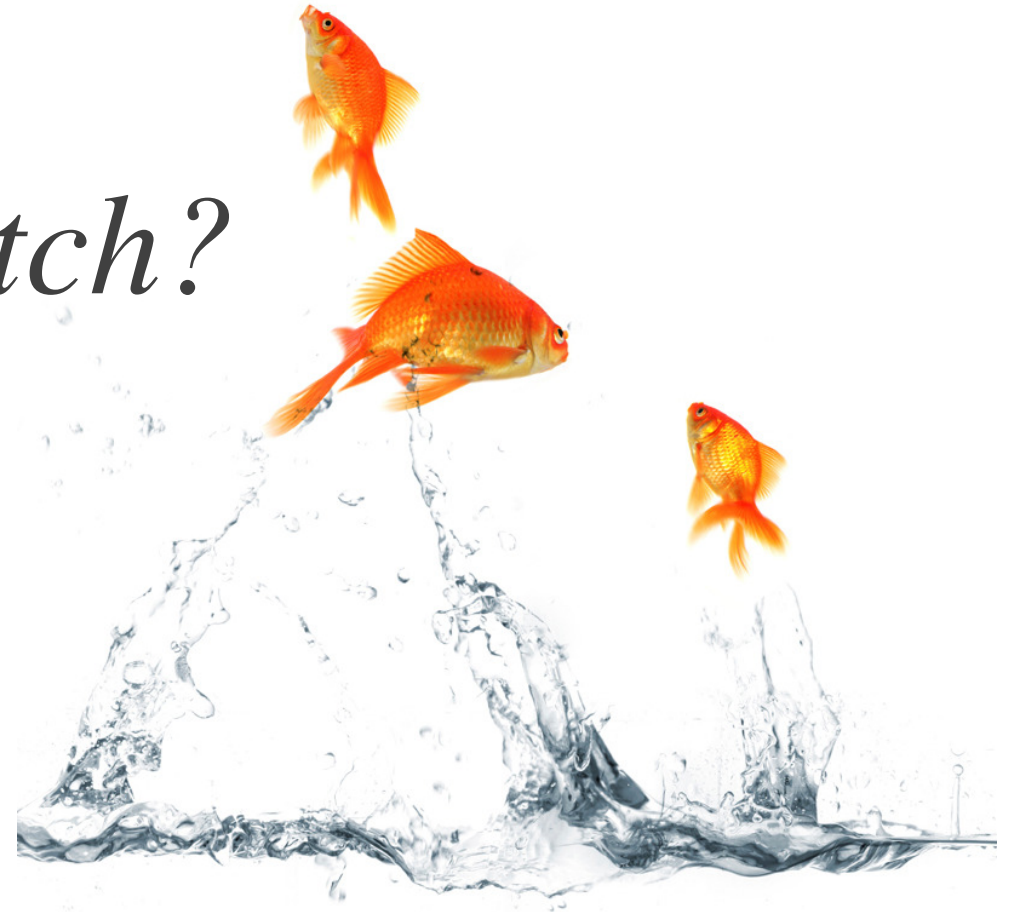 - CISCO – IP Phones
  - Set top Boxes

The Catch is…

- Not a Silver Bullet, but a Sharper Tool
- O/S Support Required!
- The benefits of RTSJ are REAL*, not theoretical
  - Architectural Flexibility
  - Predictable Solution Development
- High time to dig into RTSJ
- For more information
  - Visit www.rtsj.org
  - Visit http://www-306.ibm.com/software/webservers/realtime/

RTSJ delivers predictable performance!

* Pun intended

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Q&A