CS 147:
Computer Systems Performance Analysis
Measurement Tools

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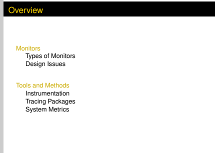
Overview

Monitors

Types of Monitors
Design Issues

Tools and Methods

Instrumentation
Tracing Packages
System Metrics



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Monitors

- A monitor is a tool used to observe system activity
- Proper use of monitors is key to performance analysis
- Also useful for other system observation purposes

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└Monitors

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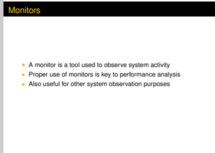

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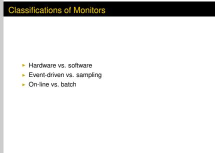
Classifications of Monitors

- Hardware vs. software
- Event-driven vs. sampling
- On-line vs. batch



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Hardware vs. Software Monitors

- Hardware monitors used primarily by hardware designers
  - Requires substantial knowledge of hardware details
  - VLSI limits monitoring possibilities
- Software monitors used (mostly) by everyone else
  - Exception: power measurement

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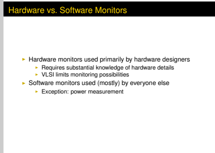

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Event-Driven vs. Sampling Monitors

- Event-driven monitors notice every time a particular type of event occurs
  - Ideal for rare events
  - Require low per-invocation overheads
- Sampling monitors check system state periodically
  - Good for frequent events
  - Can afford higher overheads

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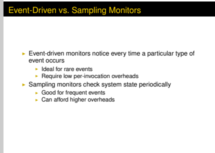

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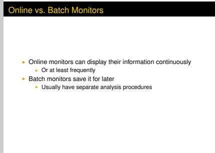
  - Or at least frequently
- Batch monitors save it for later
  - Usually have separate analysis procedures



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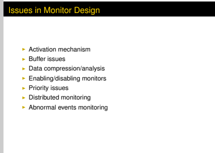
Issues in Monitor Design

- Activation mechanism
- Buffer issues
- Data compression/analysis
- Enabling/disabling monitors
- Priority issues
- Distributed monitoring
- Abnormal events monitoring



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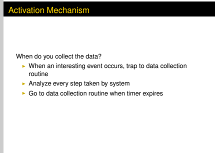
Activation Mechanism

When do you collect the data?

- When an interesting event occurs, trap to data collection routine
- Analyze every step taken by system
- Go to data collection routine when timer expires



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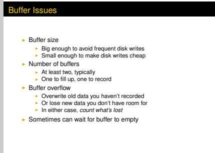
Buffer Issues

- Buffer size
  - Big enough to avoid frequent disk writes
  - Small enough to make disk writes cheap
- Number of buffers
  - At least two, typically
  - One to fill up, one to record
- Buffer overflow
  - Overwrite old data you haven't recorded
  - Or lose new data you don't have room for
  - In either case, *count what's lost*
- Sometimes can wait for buffer to empty



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Data Compression or Analysis

- Data can be literally compressed
- Or can be reduced to a summary form
- Both methods save space for holding data
- At cost of extra overhead in gathering it
- Sometimes can use idle time to compress
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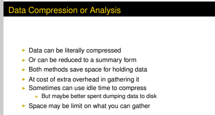

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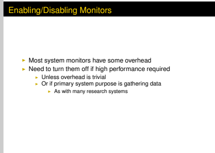
- Most system monitors have some overhead
- Need to turn them off if high performance required
    - Unless overhead is trivial
    - Or if primary system purpose is gathering data
        - As with many research systems



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- How high a priority for monitor’s operations?
- Trade off performance impact against timely & complete data gathering
- Not always simple question

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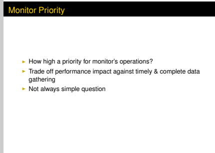

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Monitoring Abnormal Events

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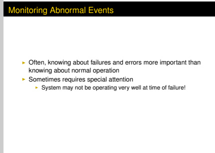
  - System may not be operating very well at time of failure!



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Monitoring Distributed Systems

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- Must deal with
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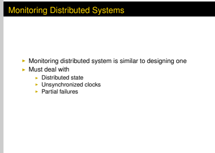
  - Unsynchronized clocks
  - Partial failures



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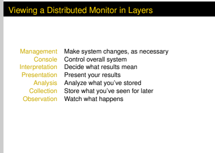
Viewing a Distributed Monitor in Layers

Management	Make system changes, as necessary
Console	Control overall system
Interpretation	Decide what results mean
Presentation	Present your results
Analysis	Analyze what you've stored
Collection	Store what you've seen for later
Observation	Watch what happens



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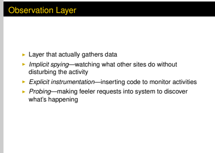
Observation Layer

- Layer that actually gathers data
- *Implicit spying*—watching what other sites do without disturbing the activity
- *Explicit instrumentation*—inserting code to monitor activities
- *Probing*—making feeler requests into system to discover what's happening



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- Data can be collected at one or several points in distributed system
- How does data get from observer to collector (if not collocated)?
  - *Advertising*—observers send it out, collectors listen and grab it
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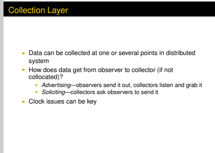

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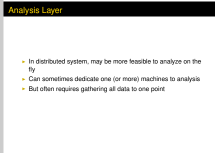

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- What practical tools and methods are available to me?
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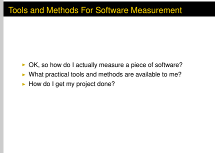

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Tools For Software Measurement

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- Tracing packages
- System-provided metrics and utilities
- Profiling

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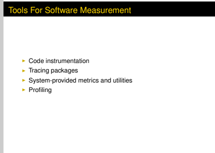

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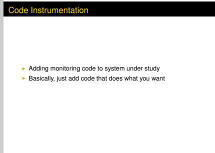

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Advantages and Disadvantages of Code Instrumentation

- + Usually most direct way to gather data
- + Complete flexibility in where to insert monitoring code
- + Strong control over costs of monitoring
- + Resulting measurements always available
- – Requires access to source
- – Requires strong knowledge of design and details of code
- – Requires recompilation to change monitoring facility
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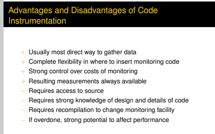

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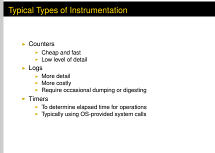
Typical Types of Instrumentation

- Counters
  - Cheap and fast
  - Low level of detail
- Logs
  - More detail
  - More costly
  - Require occasional dumping or digesting
- Timers
  - To determine elapsed time for operations
  - Typically using OS-provided system calls



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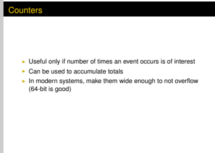

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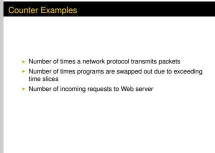
- Number of times programs are swapped out due to exceeding time slices
- Number of incoming requests to Web server



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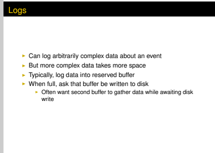

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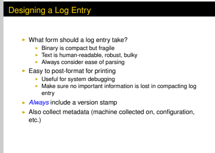
Designing a Log Entry

- What form should a log entry take?
  - Binary is compact but fragile
  - Text is human-readable, robust, bulky
  - Always consider ease of parsing
- Easy to post-format for printing
  - Useful for system debugging
  - Make sure no important information is lost in compacting log entry
- *Always* include a version stamp
- Also collect metadata (machine collected on, configuration, etc.)



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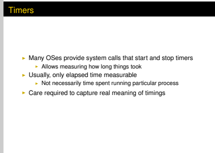

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- Basically, augment code to call monitoring routines when desired
- Akin to debuggers
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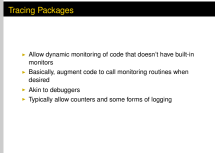

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- + Don’t need recompilation to instrument code
- + Tremendous flexibility at measurement time
- + No instrumentation overhead when you’re not using it
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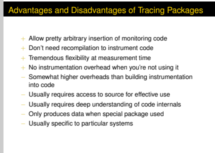

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How Do Tracing Packages Work?

Much like debuggers:

- Attach to running programs
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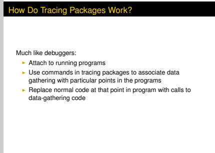
- Replace normal code at that point in program with calls to data-gathering code



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System-Provided Metrics and Utilities

- Many operating systems provide users access to some metrics
- Most operating systems also keep some form of accounting logs
- Lots of information can be gathered this way

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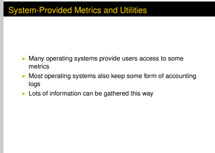

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What a Typical System Provides

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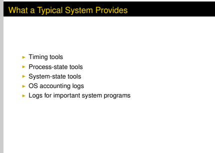
- Process-state tools
- System-state tools
- OS accounting logs
- Logs for important system programs



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- E.g., Unix `time` command gives system, user, and elapsed time
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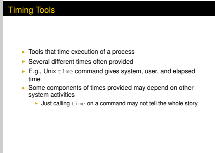
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Process-State Tools

- Many systems have ways for users to learn state of their processes
- Typically provide information about
    - Time spent running process so far
    - Process size (virtual/real)
    - Status (running, waiting for I/O, etc.)
    - Priority
    - I/O history

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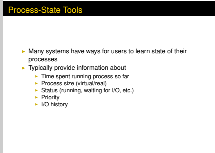
 └System Metrics
  └Process-State Tools



Process-State Tools

- Many systems have ways for users to learn state of their processes
- Typically provide information about
    - Time spent running process so far
    - Process size (virtual/real)
    - Status (running, waiting for I/O, etc.)
    - Priority
    - I/O history

Using Process-State Tools

- Typically can’t monitor process state continuously
  - Updates not provided every time things change
- Can get snapshots on demand
  - Most useful for sampling monitors

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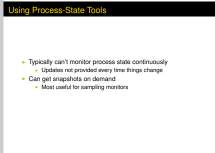
└Tools and Methods
  └System Metrics
    └Using Process-State Tools



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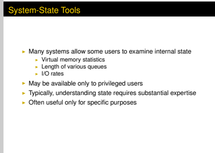
System-State Tools

- Many systems allow some users to examine internal state
  - Virtual memory statistics
  - Length of various queues
  - I/O rates
- May be available only to privileged users
- Typically, understanding state requires substantial expertise
- Often useful only for specific purposes



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OS Accounting Logs

- Many operating systems maintain logs of significant events
- Based on either event-driven or sampling monitors
- Examples:
  - Logins
  - Quota violations
  - Program executions
  - Device failures

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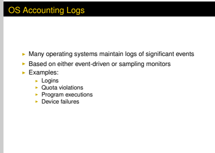

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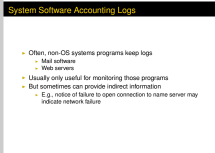
System Software Accounting Logs

- Often, non-OS systems programs keep logs
  - Mail software
  - Web servers
- Usually only useful for monitoring those programs
- But sometimes can provide indirect information
  - E.g., notice of failure to open connection to name server may indicate network failure



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