6.033 Computer System Engineering

Spring 2009

MASSACHUSETTS
INSTITUTE OF
TECHNOLOGY

# Fault-tolerant Computing

Frans Kaashoek

# Where are we in 6.033?

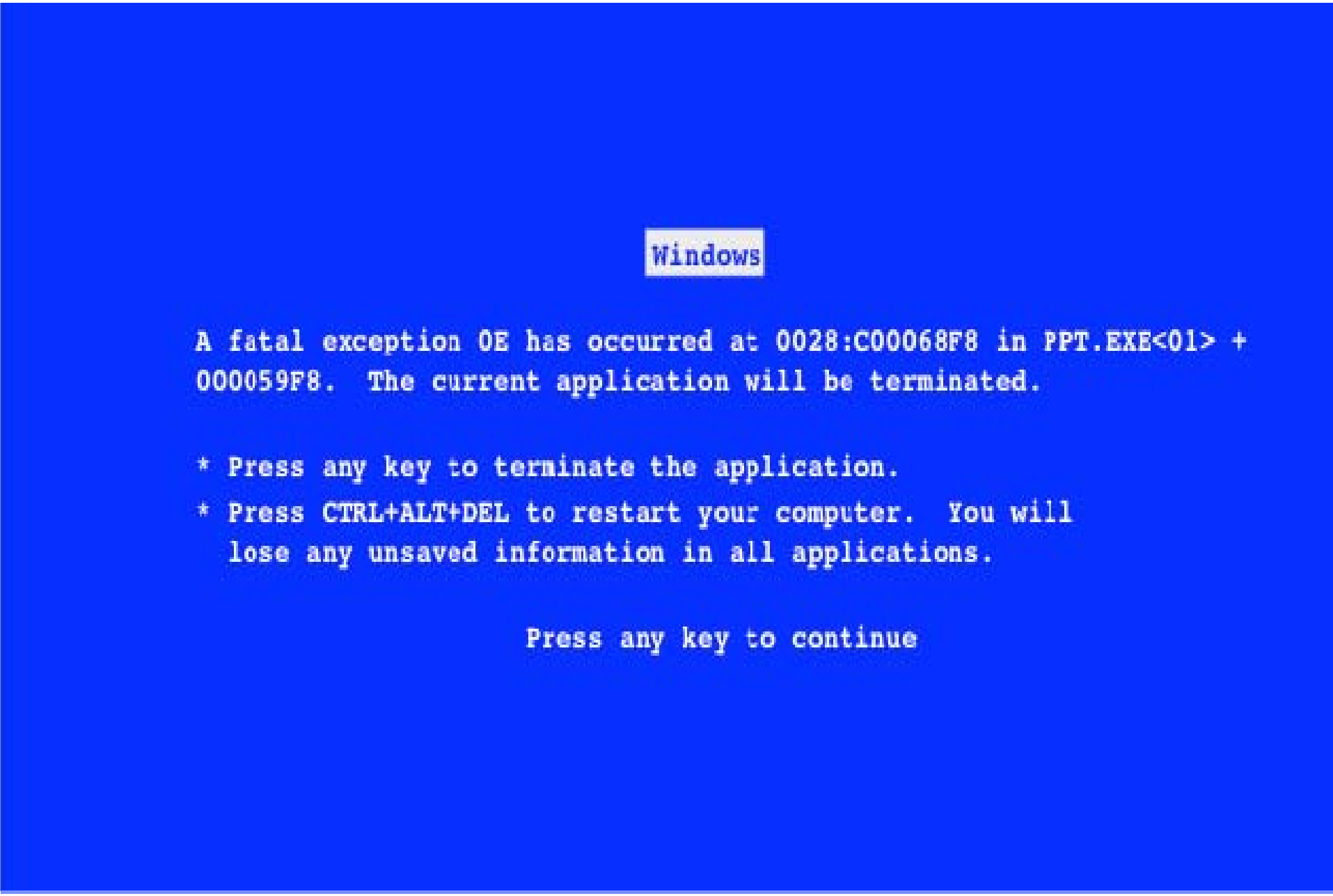
- Modularity to control complexity
  - Names are the glue to compose modules
- Strong form of modularity: client/server
  - Limit propagation of errors
- Implementations of client/server:
  - In a single computer using virtualization
  - In a network using protocols
- Compose clients and services using names
  - DNS

# How to respond to failures?

- Failures are contained; they don't propagate
  - Benevolent failures
- Can we do better?
  - Keep computing despite failures?
  - Defend against malicious failures (attacks)?
- Rest of semester: handle these "failures"
  - Fault-tolerant computing
  - Computer security

# Fault-tolerant computing

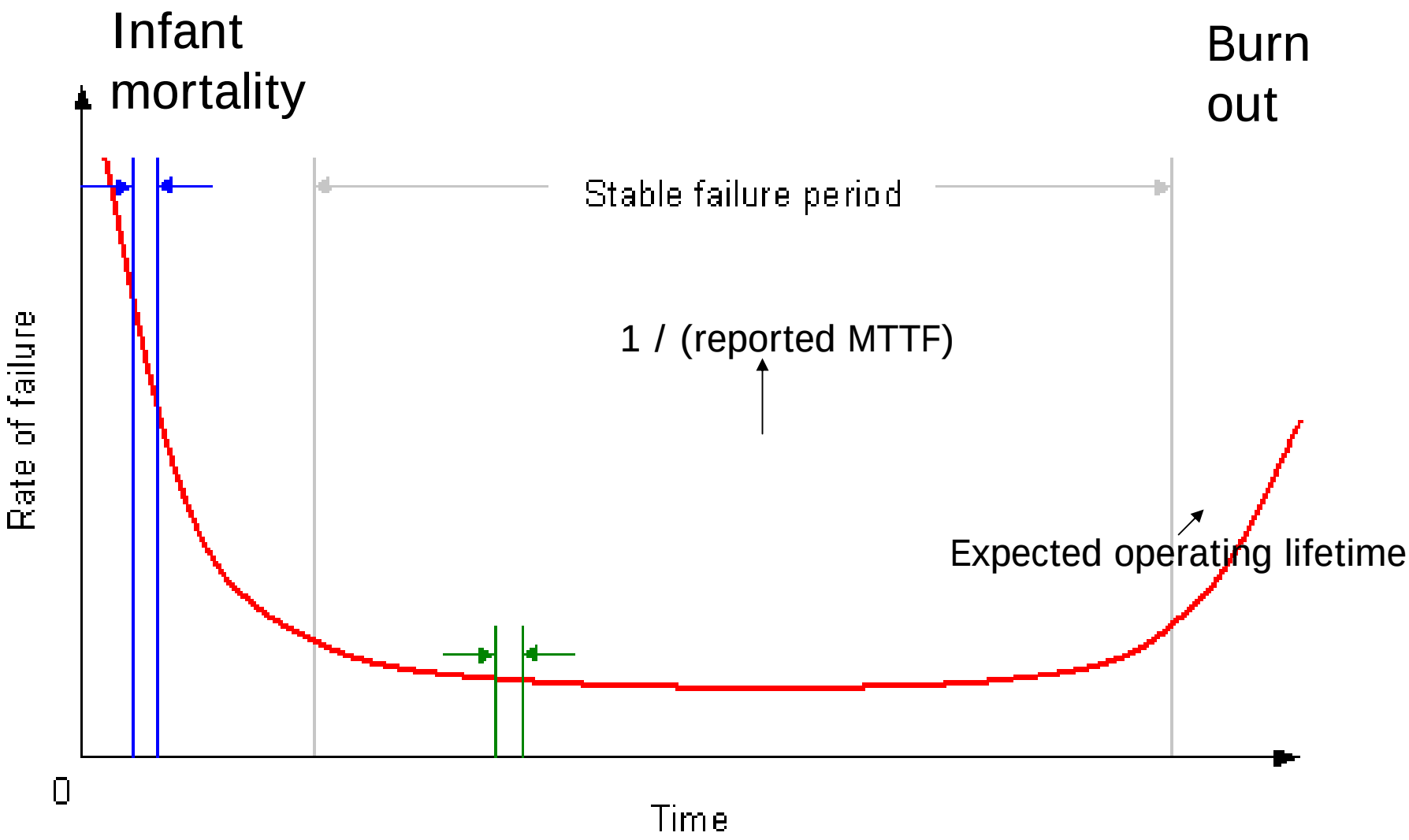
- General introduction: today
  - Replication/Redundancy
- The hard case: transactions
  - updating permanent data in the presence of concurrent actions and failures
- Replication revisited: consistency


Windows
A fatal exception 0E has occurred at 0028:C00068F8 in PPT.EXE<01> +
000059F8. The current application will be terminated.
* Press any key to terminate the application.
* Press CTRL+ALT+DEL to restart your computer. You will
lose any unsaved information in all applications.
Press any key to continue

# Availability in practice

- Carrier airlines (2002 FAA fact book)
  - 41 accidents, 6.7M departures
  - ✓ 99.9993% availability
- 911 Phone service (1993 NRIC report)
  - 29 minutes per line per year
  - ✓ 99.994%
- Standard phone service (various sources)
  - 53+ minutes per line per year
  - ✓ 99.99+%
- End-to-end Internet Availability
  - ✓ 95% - 99.6%

# Disk failure conditional probability distribution




Bathtub curve

# Fail-fast disk

```
failfast_get (data, sn) {
        get (s, sn);
        if (checksum(s.data) = s.cksum) {
                data ← s.data;
                return OK;
        } else {
                return BAD;
        }
}
```

# Careful disk

```
careful_get (data, sn) {
        r ← 0;
        while (r < 10) {
                r ← failfast_get (data, sn);
                if (r = OK) return OK;
                r++;
        }
        return BAD;
}
```

# Durable disk (RAID 1)

```
durable_get (data, sn) {
        r ← disk1.careful_get (data, sn);
        if (r = OK) return OK;
        r ← disk2.careful_get (data, sn);
        signal(repair disk1);
        return r;
}
```