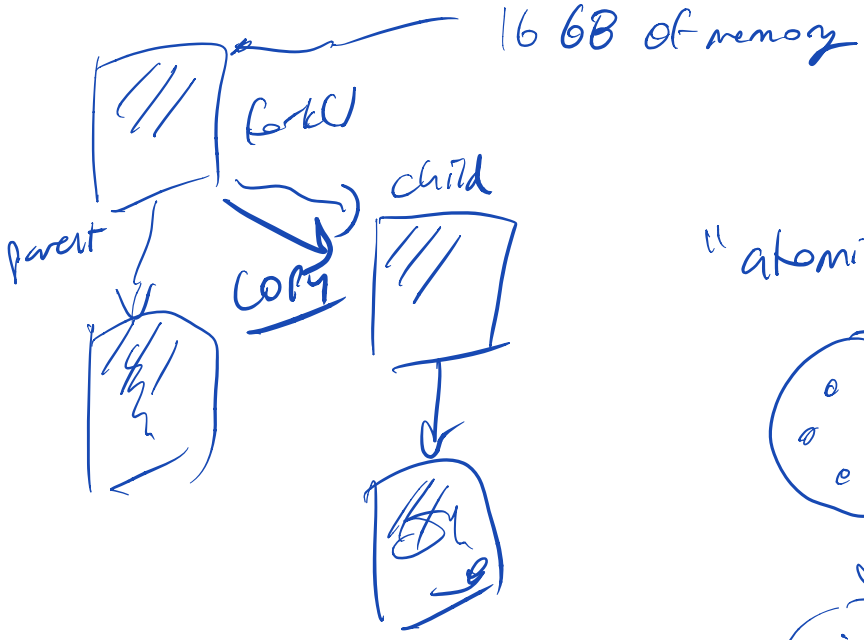
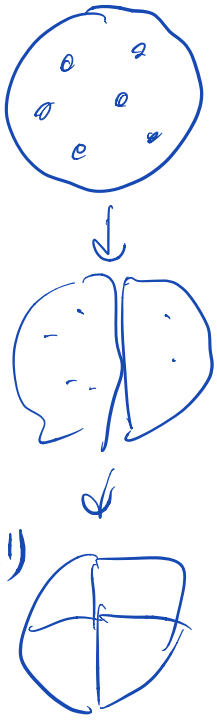
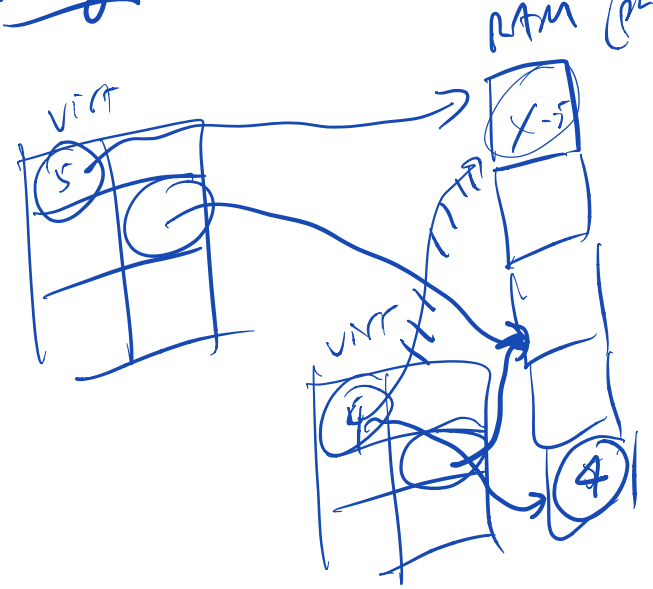


"atomically"



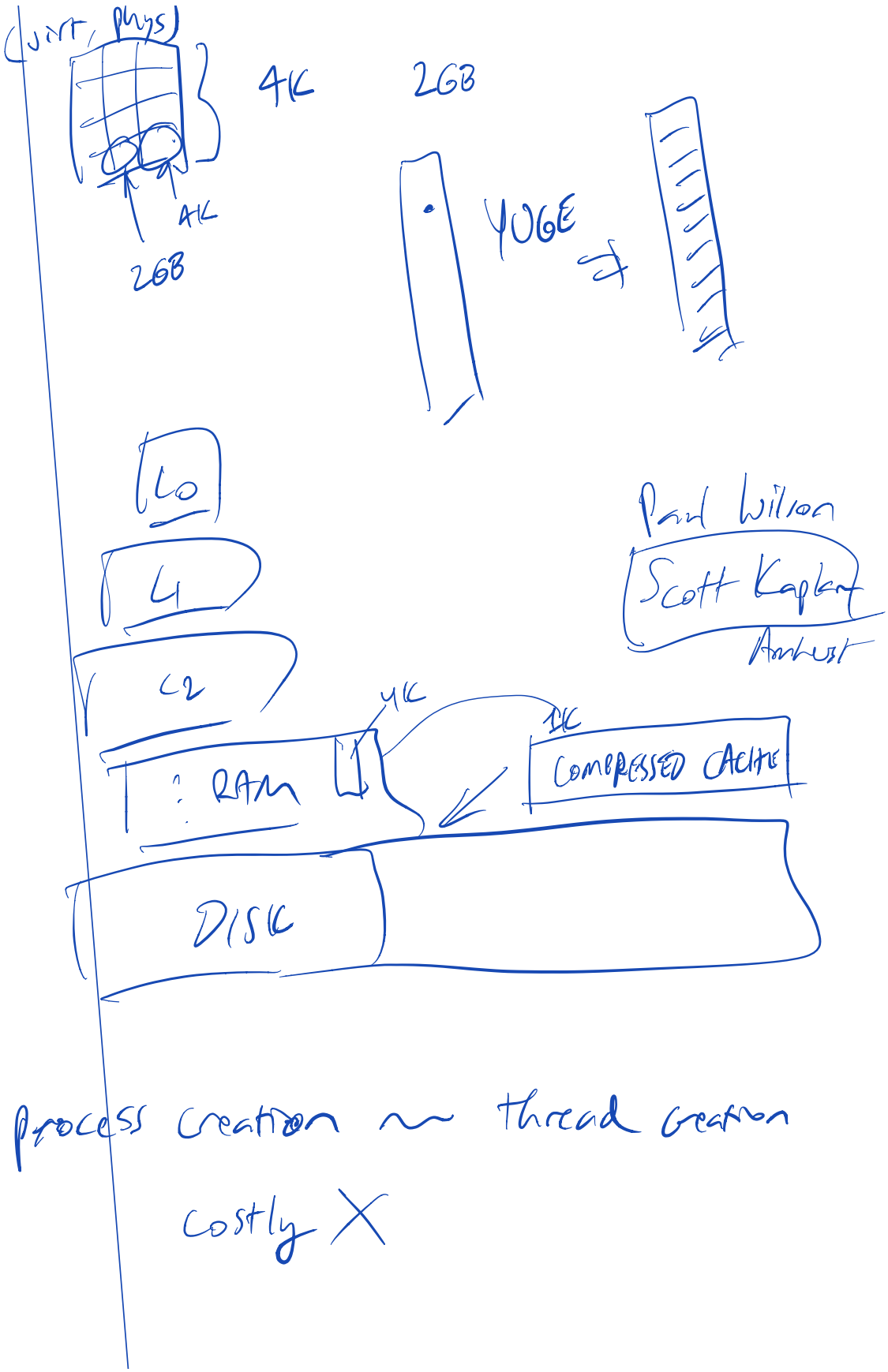
eager copying X

lazy on-demand



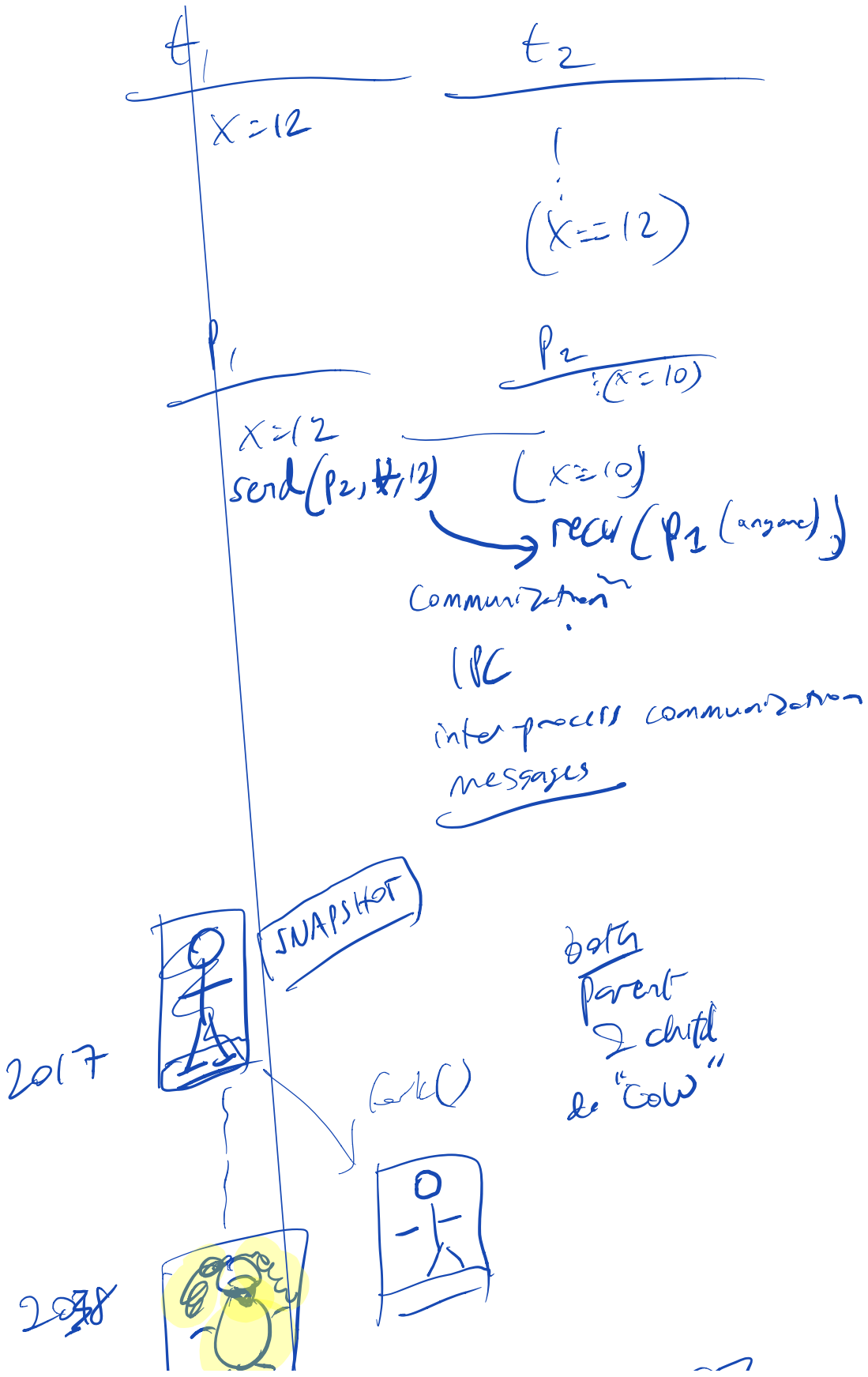
atomos
"indivisible"

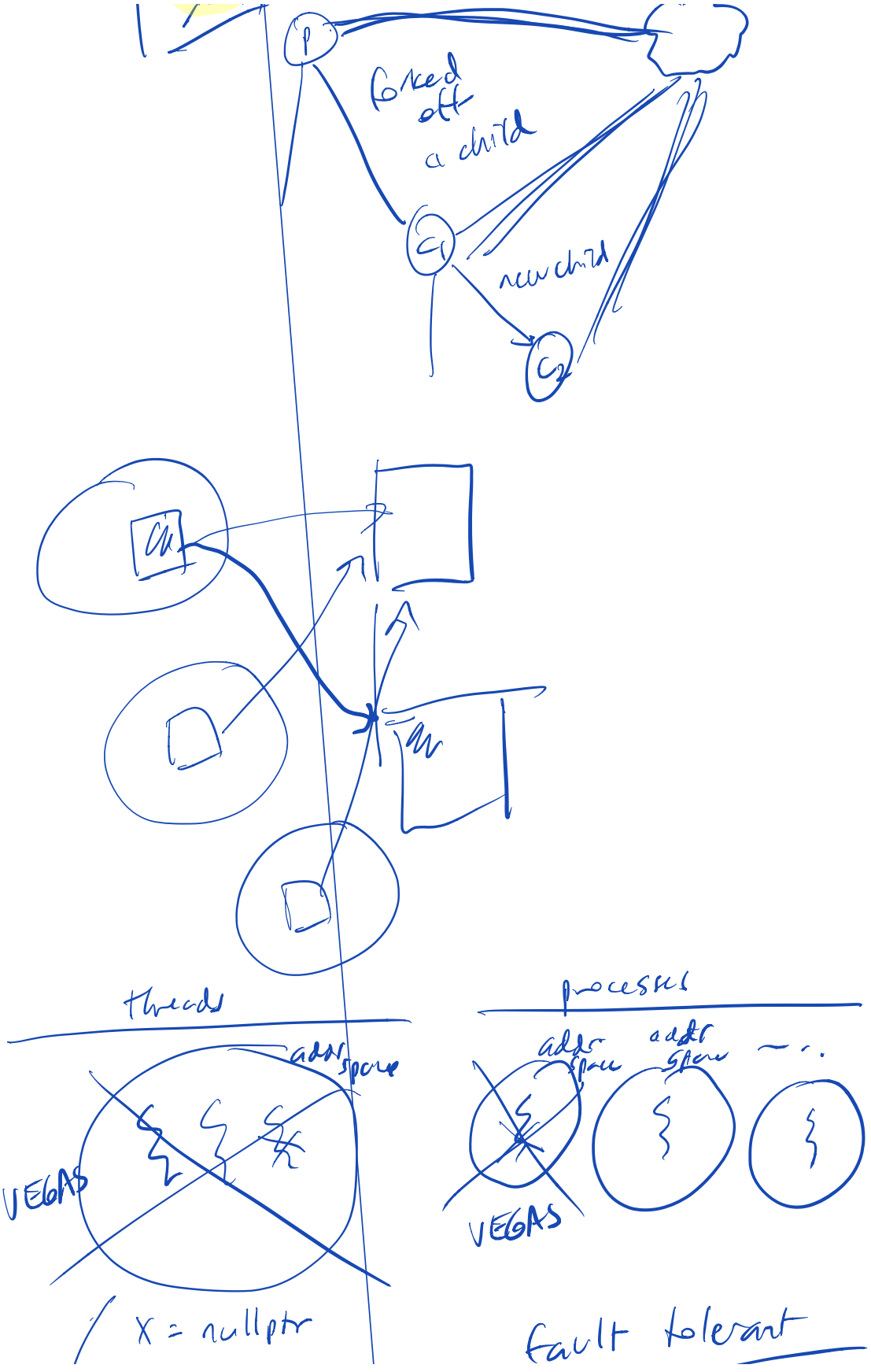
Copy-on-write

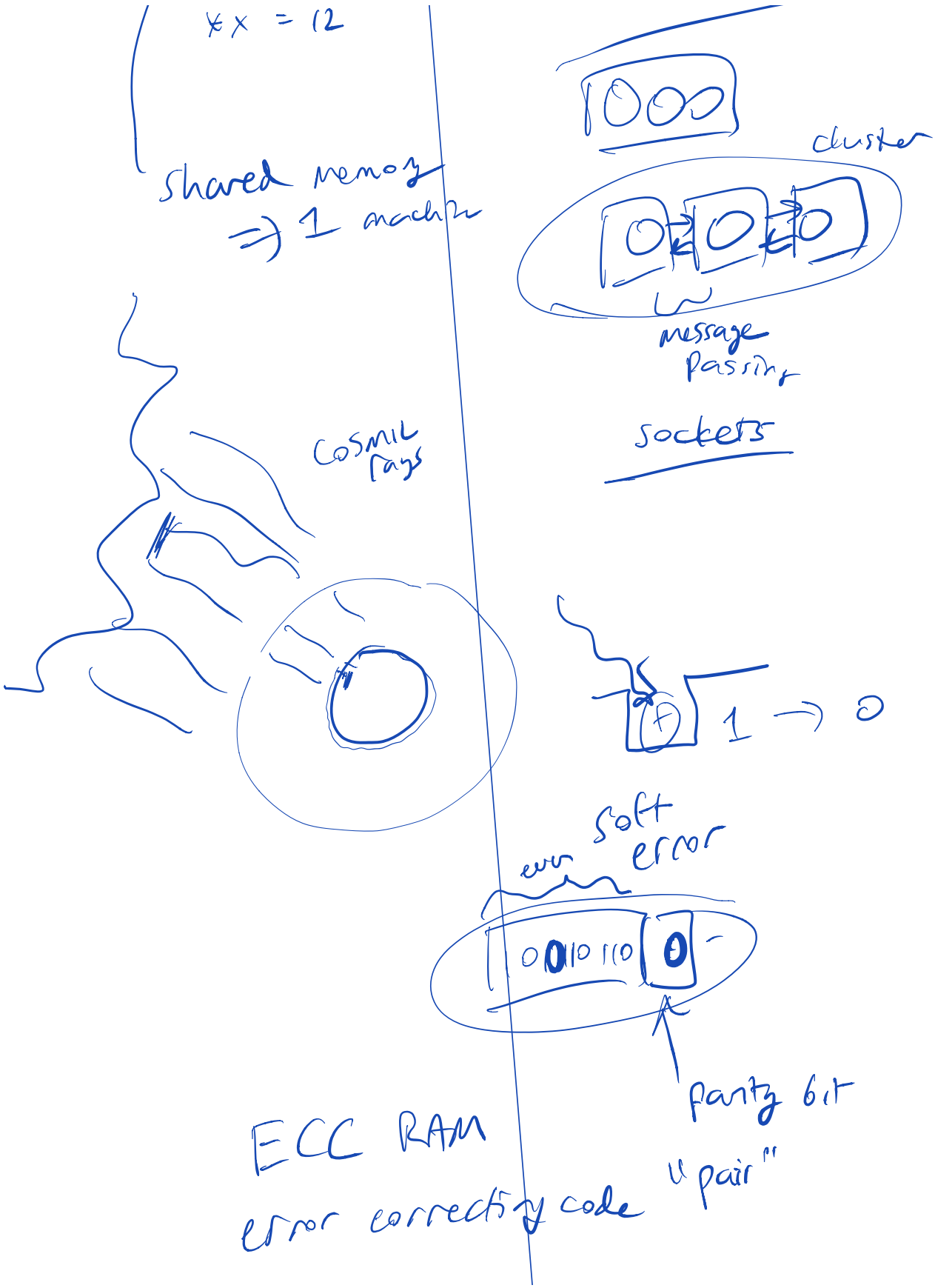


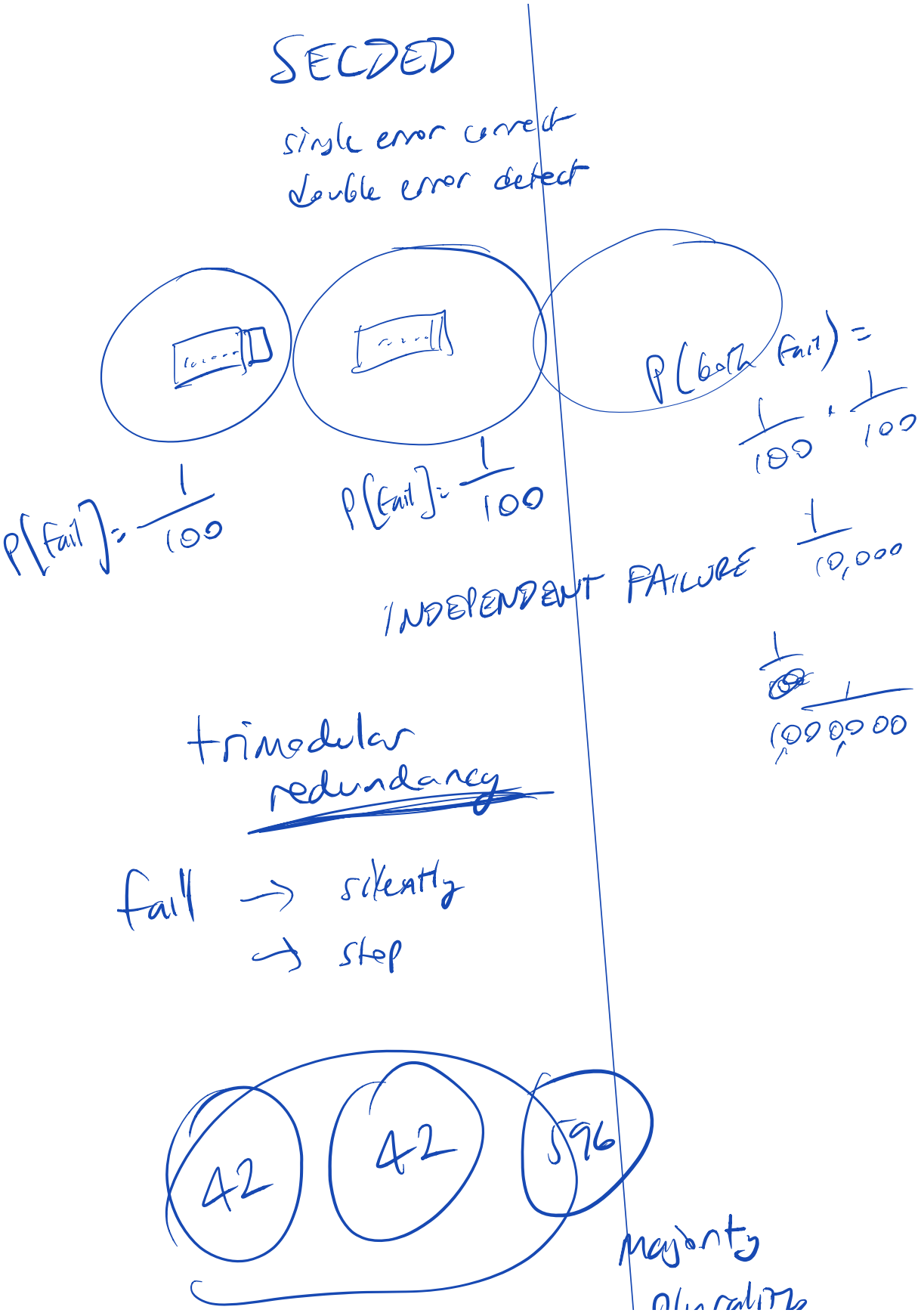
process creation ~ thread creation

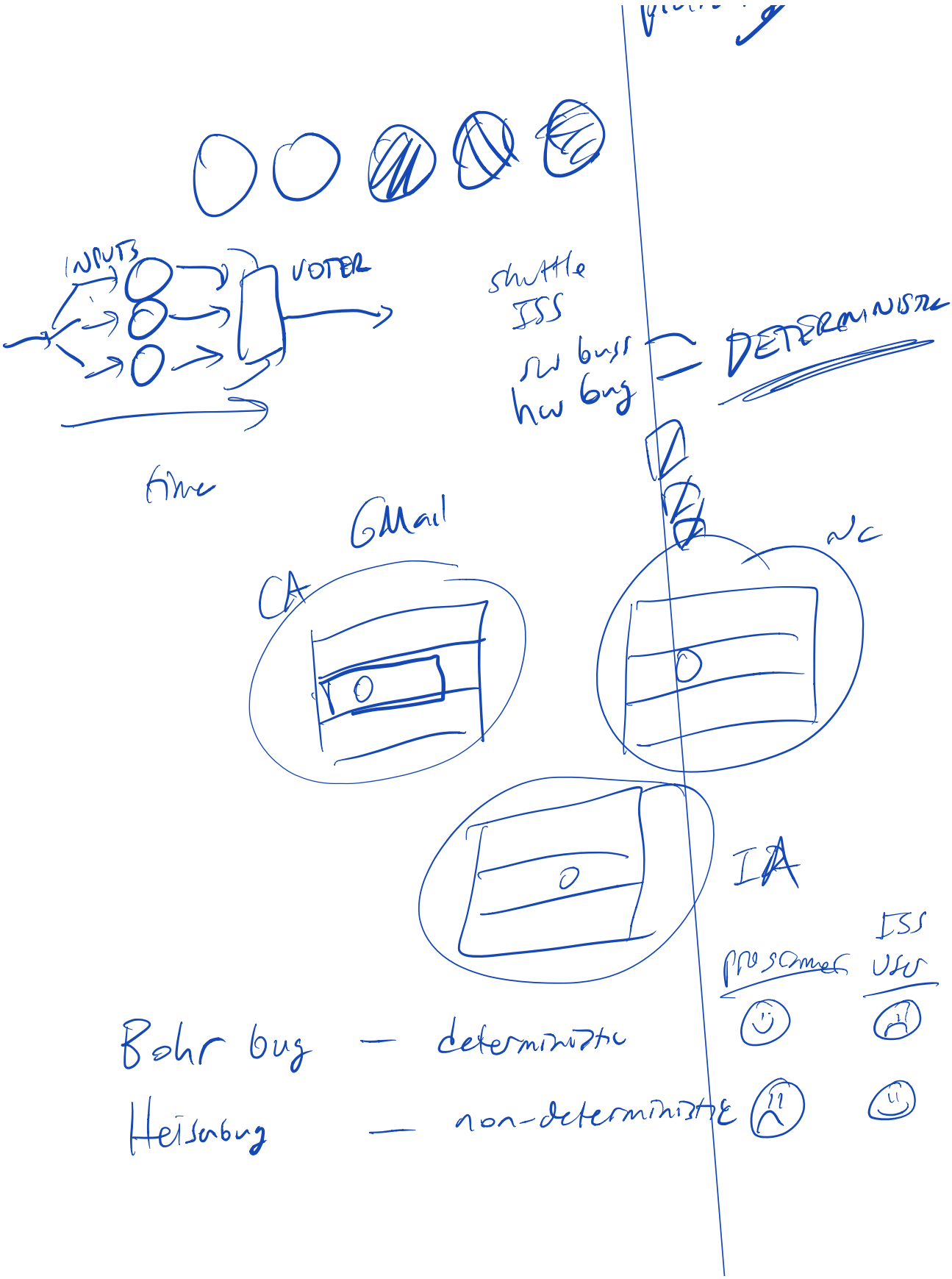
costly X

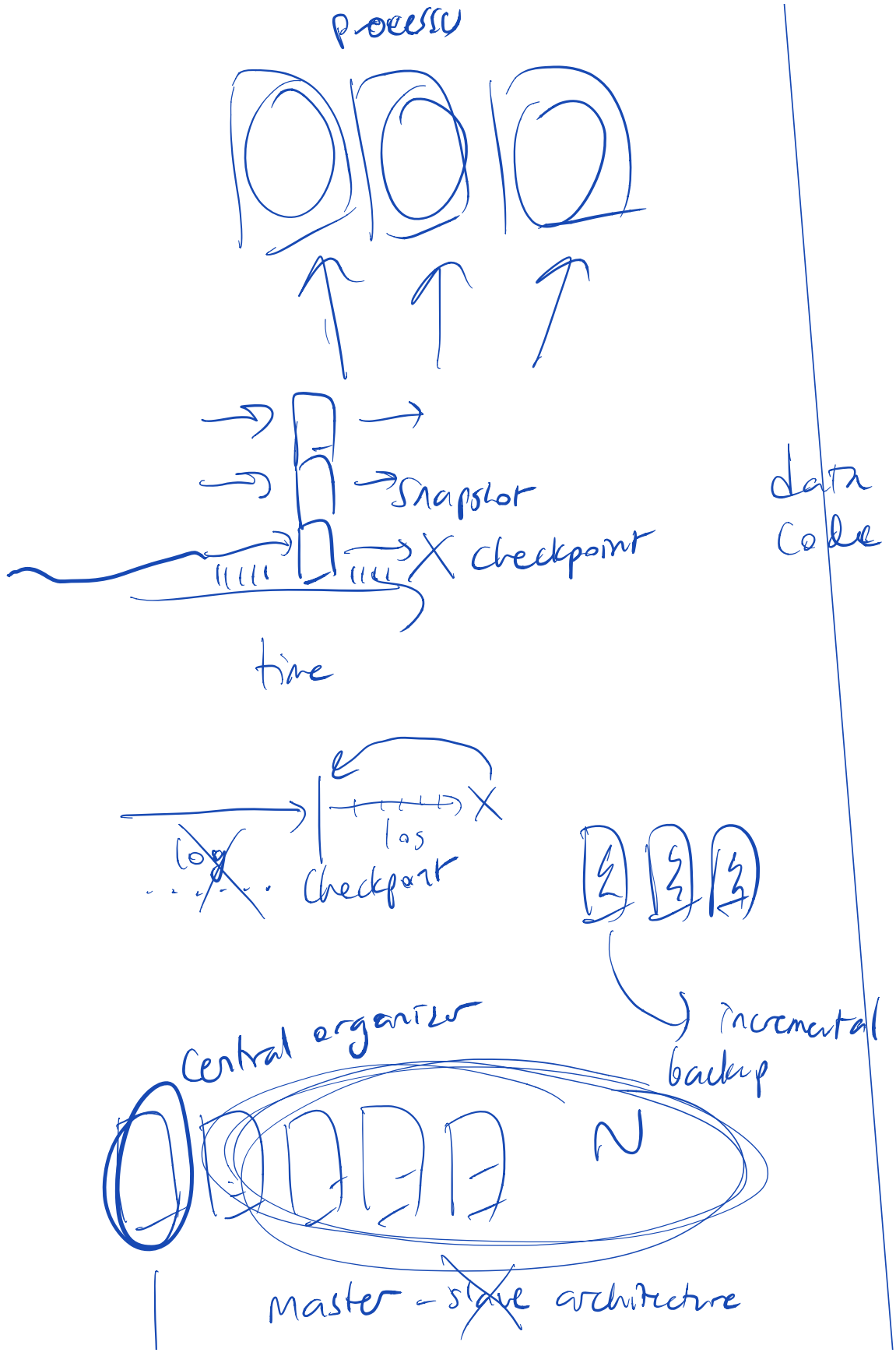

t1
t2
x=12
(x==12)
P1
P2
(x=10)
x=12
send(P2, &12)
(x=10)
recv(P1 (argone))
Communication
IPC
inter process communication
messages
SNAPSHOT
2017
fork()
both
Parent
2 child
& "CoW"
2018

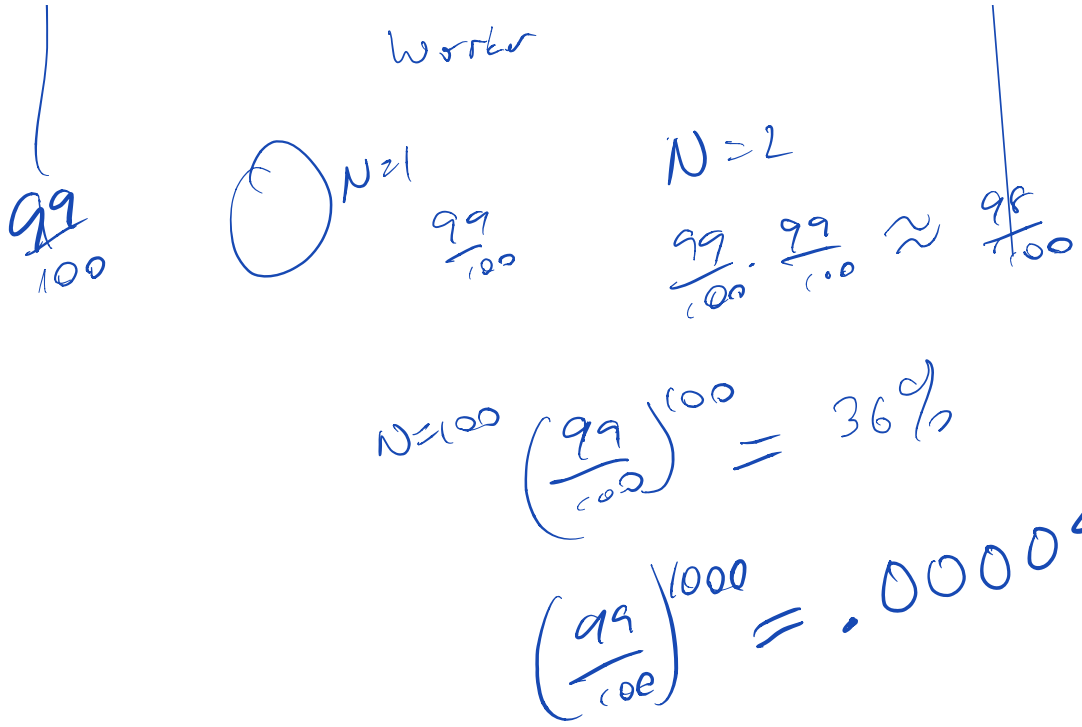

P
forked off a child
C1
new child
C2
Threads
addr space
VEGAS
X = nullptr
processes
addr space
addr space
VEGAS
fault tolerant


*x = 12
shared memory
⇒ 1 machine
cluster
message passing
sockets
cosmic rays
1 → 0
soft error
ECC RAM
error correcting code
parity bit
"pair"


SECDED
single error correct
double error detect
P[fail] = 1/100
P[fail] = 1/100
P(both fail) = 1/100 * 1/100
1/10,000
INDEPENDENT FAILURE
1/100,000
trimodular redundancy
fail → silently
→ stop
42
42
596
majority


INPUTS
VOTER
time
shuttle
ISS
sw bugs
hw bug
DETERMINISTIC
GMail
CA
NC
IA
ISS
Bohr bug — deterministic
Heisenbug — non-deterministic


processes
Snapshot
checkpoint
time
data
Code
log
log
Checkpoint
incremental
backup
Central organizer
N
master - slave architecture


Worker
N=1
N=2
99/100
99/100
99/100 · 99/100 ≈ 98/100
N=100 (99/100)^100 = 36%
(99/100)^1000 = .00004