5. TOY Simulator

TOY Simulator

Goal. Write a program to "simulate" the behavior of the TOY machine.

- TOY simulator in Java.
- TOY simulator in TOY!

```
public class TOY {
   public static void main(String[] args) {
      int pc    = 0x10;           // program counter
      int[] R   = new int[16];    // registers
      int[] mem = new int[256];   // main memory

      // READ IN .toy FILE

      while (true) {
         // FETCH INSTRUCTION and DECODE
         ...
         // EXECUTE
         ...
      }
   }
}
```

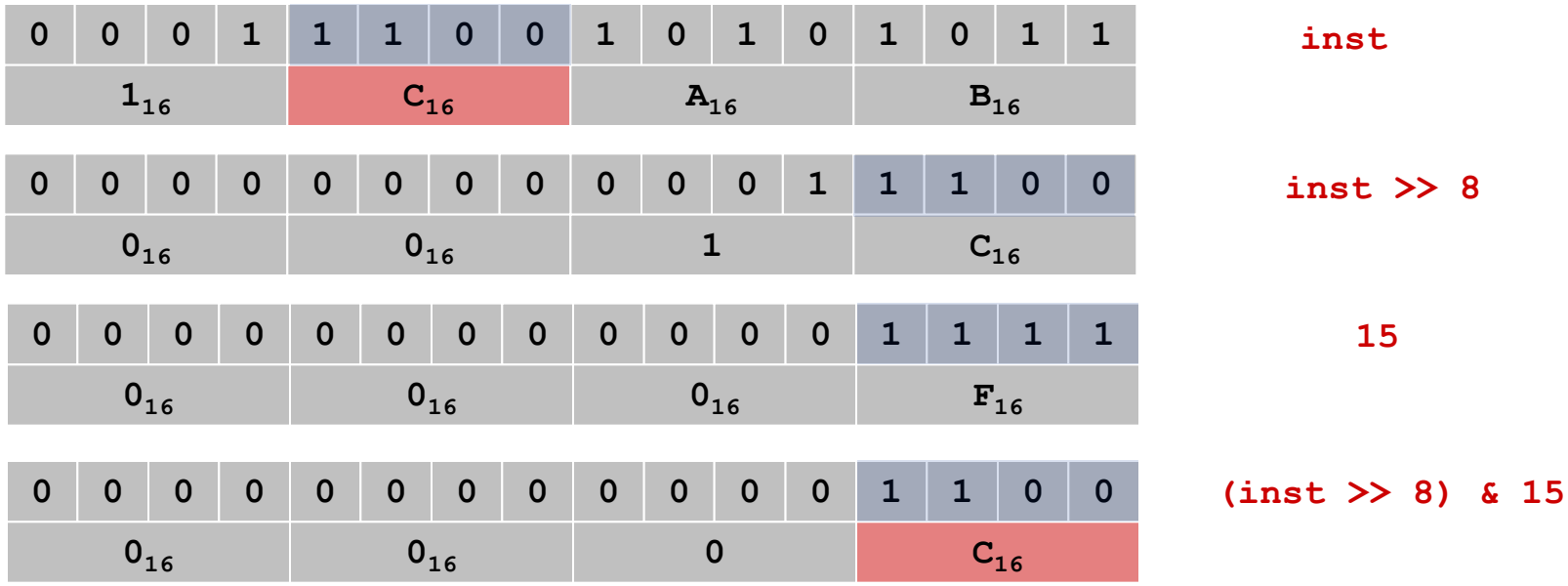
```
% java TOY add-stdin.toy
A012
002B
A03D
```

standard input

standard output

TOY Simulator: Fetch

Fetch. Extract destination register of `1CAB` by shifting and masking.




```
int inst = mem[pc++];           // fetch and increment
int op   = (inst >> 12) &  15;  // opcode    (bits 12-15)
int d    = (inst >>  8) &  15;  // dest d    (bits 08-11)
int s    = (inst >>  4) &  15;  // source s  (bits 04-07)
int t    = (inst >>  0) &  15;  // source t  (bits 00-03)
int addr = (inst >>  0) & 255;  // addr      (bits 00-07)
```

TOY Simulator: Execute

```
if (op == 0) break;         // halt
else if (op == 0x01) R[d] = R[s] +  R[t];
else if (op == 0x02) R[d] = R[s] -  R[t];
else if (op == 0x03) R[d] = R[s] &  R[t];
else if (op == 0x04) R[d] = R[s] ^  R[t];
else if (op == 0x05) R[d] = R[s] << R[t];
else if (op == 0x06) R[d] = R[s] >> R[t];
else if (op == 0x07) R[d] = addr;
else if (op == 0x08) R[d] = mem[addr];
else if (op == 0x09) mem[addr] = R[d];
else if (op == 0x10) R[d] = mem[R[t]];
else if (op == 0x11) mem[R[t]] = R[d];
else if (op == 0x12) if (R[d] == 0) pc = addr;
else if (op == 0x13) if (R[d] >  0) pc = addr;
else if (op == 0x14) pc = R[d];
else if (op == 0x15) R[d] = pc; pc = addr;
```

TOY Simulator: Omitted Details

Omitted details.

- Register 0 is always 0.
  - reset `R[0] = 0` after each fetch-execute step

- Standard input and output.
  - if `addr` is `FF` and opcode is load (indirect) then read in data
  - if `addr` is `FF` and opcode is store (indirect) then write out data

- TOY registers are 16-bit integers; program counter is 8-bit.
  - Java `int` is 32-bit; Java `short` is 16-bit
  - use casts and bit-whacking

Complete implementation. See `TOY.java` on booksite.

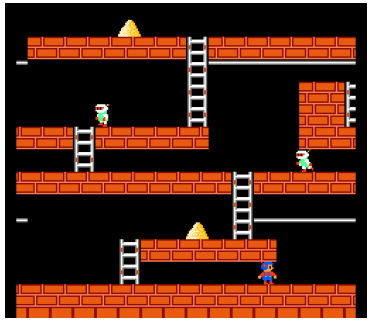
Simulation

Consequences of simulation.

- Test out new machine or microprocessor using simulator.
  (cheaper and faster than building actual machine)
- Easy to add new functionality to simulator.
  (trace, single-step, breakpoint debugging)
- Reuse software from old machines.

Ancient programs still running on modern computers.

- Ticketron.
- Lode Runner on Apple IIe.



Backwards Compatibility

Q. Why is standard US rail gauge 4 feet, 8.5 inches?

Backwards Compatibility

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A. Same spacing as wheel ruts on old English roads.

Mail wagon, circa 1890

Backwards Compatibility

Q. Why is standard US rail gauge 4 feet, 8.5 inches?

A. Wheel rut spacing same as old Roman war chariots.

Roman chariot (marble), Vatican museum

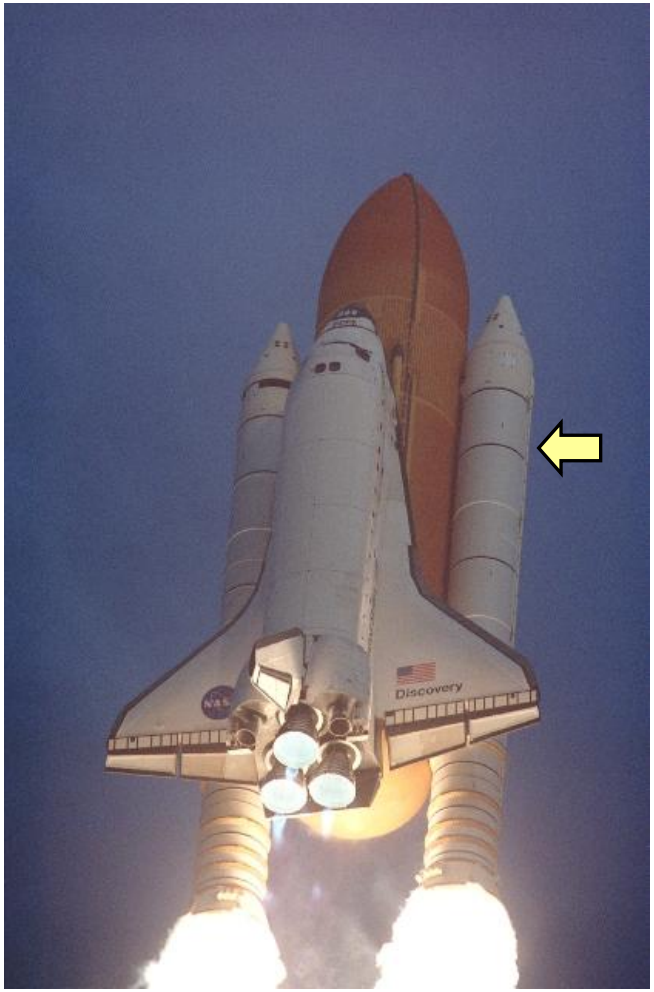
Backwards Compatibility

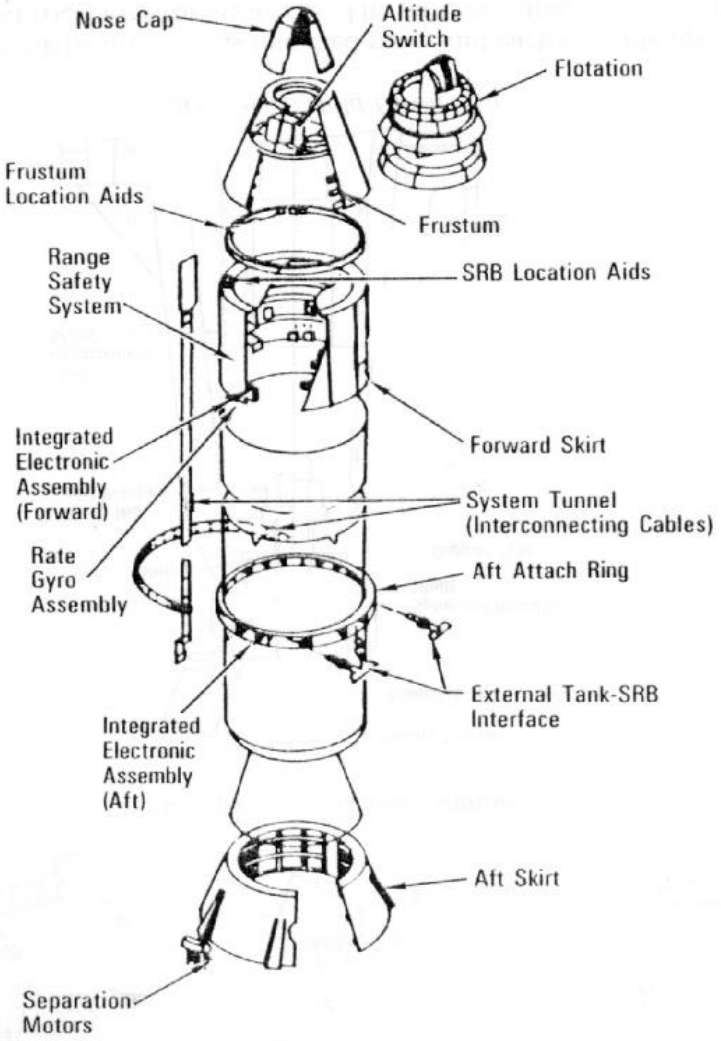
Q. Why is standard US rail gauge 4 feet, 8.5 inches?

A. Roman war chariot wide enough to accommodate "back ends" of two war horses!

Backwards Compatibility

Q. Why is Space Shuttle SRB long and narrow?





Solid Rocket Booster—Exploded View

Simulation and Backwards Compatibility

Napoleon's march on Russia.

- Progress slower than expected.
- Eastern European ruts didn't match Roman gauge.
- Stuck in the field during Russian winter instead of Moscow.
- Lost war.

Simulation tradeoff:

- Simulation essential to reuse old software.
- Maintaining backward compatibility can lead to inelegance and inefficiency.
- Simulation needed to conquer world.