15-1/ Safety

(÷ 1 0) (5 3)

$E[(u\ v)] \longrightarrow E[\text{abort "Tried to call non-function"}]$
where $u \in p, \lambda$

$\langle v, \_, \text{kapp}(u) \_ () \ k \rangle$
$\longmapsto \langle \text{abort "Tried to call non-function"}, \_, k \rangle$

15-2/

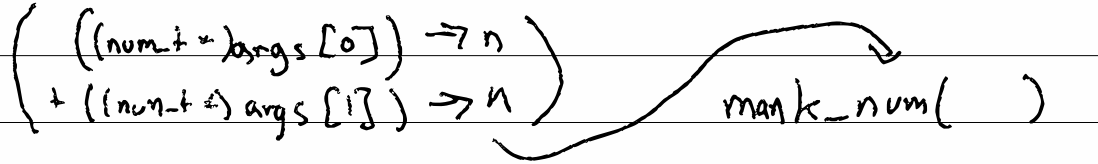
```
switch ( c->tag ) {
  case C_IF: ...
    :
  case C_LAM: ...
  case C_NUM:
  case C_BOOL:
    switch ( k->tag ) {
      case K_IF: ...
      case K_APP:
        if ( k->es->tag == EMPTY ) {
          if ( k->vs[0] ->tag == CLO ) { ... }
                              == PRIM ) { ... }
          else { ... do the abort sign ...
```

15-3/ A <u>safe</u> kernel of language

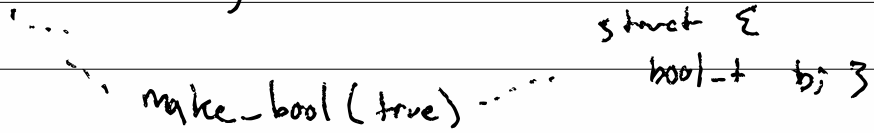
is when the lowest level enforces the invariants of the languages.

.... This is expensive!

... the code in Delta for addition ...



(+ true false) ⟶ 1



15-4/ JS, Py, Ruby, Racket, ...
all intend to be safe

C is not like, nor is C++

unsafe

15-5/ How to have an unsafe kernel (fast)
AND a safe language?

OLD:

+ is the kernel's plus

NEW:

+ is in the standard library

unsafe_+ is the kernel's plus (#%+)

15-6/

```
(define (+ x y)
  (if (and (number? x)
           (number? y))
      (unsafe-+ x y)
      (throw "+: given non-numbers")))
```

Must add number? to the kernel

box? boolean? pair? unit? inl? inr?
continuation? function? primitive-arity
function-arity primitive?

15-7/ (+ 1 2 3) (+ 1)

desugar $[f, x_0, \ldots, x_n] =$

```
(if (and (procedure? f)
         (= n (procedure-arity f)))
    (f x0 ... xn)
    (throw "not a fun or wrong arg"))

(define (procedure? x)
  (or (function? x) (primitive? x) (continuation? x)))
(define (procedure-arity x)
  (if (function? x) (function-arity x)
      (if (primitive? x) (primitive-arity x) 1)))
```

J → J

15-8) (+ 1 2) (if True x y) ⇒ x

⇒ desugar

(if (and (procedure? +) (= (procedure-arity +) 2))
(+ 1 2) ...)

⇒ optimizer (+ 1 2)

⇒ (if (and (num? 1) (num? 2))
(unsafe-+ 1 2) ...)

⇒ (unsafe-+ 1 2)

(L lwe 3)

15-9/ violation of invariant:

- what was sent — true ⇒ val
- what was supposed — num ⇒ ctc
- who sent it — you ⇒ pos label
- who recv'd it — + ⇒ neg label

Software contracts — express and enforce invariants

```
(protect ctc val pos neg)
⇒ (if (ctc val) val
      (error "expected " ctc " but got " val
             " from " pos " to " neg))
```

15-10] desugar ["+", x, y] =>

(unsafe-+ (protect number? x "line 27" "+")
(protect number? y "line 29" "+"))

15-11/ A flat contract is one on an atom ie value.

number? bool?

Concat Map : (Num ⇒ Str) x List(Num) ⇒ Str

```
protect (listof ctc) v pos neg =>
  (and (list? v) (checkall ctc v pos neg)
(check all ctc [] pos neg => true
checkall ctc (a:d) pos neg =>
  (and (protect ctc a pos neg)
       (checkall ctc d pos neg)
```

15-12/

```
                    dom              rng
protect   (Num -> Str)   x   pos neg =>
(if (and (procedure? x) (= (procedure-arity x) 1))
   (λ (arg)
    (protect rng (x (protect dom arg neg pos))
                pos neg)
```

higher-order contract