⍝ The Co-dfns Compiler

⍝ High-performance, Parallel APL Compiler

:Namespace CODFNS

```
          ⎕IO ⎕ML ⎕WX ← 0 1 3
               VERSION ← 2017 11 0
              COMPILER ← 'vsc'
            BUILD∆PATH ← 'build'
             AF∆PREFIX ← '/usr/local'
                AF∆LIB ← 'afcuda'
    VISUAL∆STUDIO∆PATH ← 'C:\Program Files (x86)\Microsoft Visual Studio\2017\Enterprise\VC\Auxiliary\Build'

  Cmp  ← {_ ← {22 :: ⍬ ⋄ ω ⎕NERASE ω ⎕NTIE 0} so ← BSO α
          _ ← (⍎COMPILER) α ⊣ (BUILD∆PATH, '/', α, '_', COMPILER, '.cpp') put⍨ gc tt ⊃ a n ← ps ω
         22  ::  'COMPILE ERROR' ⎕SIGNAL 22
             n ⊣ ⎕NUNTIE so ⎕NTIE 0}
  MkNS ← {NS ⊣ α∘{NS.⍎α mkf ω}¨ (1 = 1 ⌷ ⍉ω)⌿ 0 ⌷ ⍉ω ⊣ NS ← #.⎕NS ⍬}
  Fix  ← {α MkNS α Cmp ω}
  Xml  ← {⎕XML (0 ⌷ ⍉ω), (,∘⍕⌿ 2 ↑ 1 ↓ ⍉ω), (⊂''), ⍪(⊂(¯3 + ≢⍉ω) ↑ ,¨'nrsgvyel') ,∘⍪¨ ↓ ⍕∘,¨ ⍉ 3 ↓ ⍉ω}
  BSO  ← {BUILD∆PATH, '/', ω, '_', COMPILER, soext ⍬}
  MKA  ← {mka ⊂ ω ⊣ 'mka' ⎕NA 'P  ', (BSO α), '|mkarray <PP'}
  EXA  ← {exa ⍬ ω ⊣ 'exa' ⎕NA (BSO α), '|exarray >PP P'}
  FREA ← {frea ω ⊣ 'frea' ⎕NA (BSO α), '|frea P'}

soext ← {'.dll' '.so' '.dylib' ⊃⍨ 'vsc' 'gcc' 'clang' ⍳ ⊂COMPILER}
  tie ← {0 :: ⎕SIGNAL ⎕EN ⋄ 22 :: ω ⎕NCREATE 0 ⋄ 0 ⎕NRESIZE ω ⎕NTIE 0}
  put ← {s ← (¯128 + 256 | 128 + 'UTF-8' ⎕UCS α) ⎕NAPPEND (t ← tie ω) 83 ⋄ 1 : r ← s ⊣ ⎕NUNTIE t}
  mkf ← {fn  ← BUILD∆PATH, '/', α, '_', COMPILER, (soext ⍬), '|', ('∆' ⎕R '__' ⊢ ω), '_dwa '
         f  ← ω, '←{_←''dya''⎕NA''', fn, '>PP <PP <PP''  ⋄ '
         f ,← '_←''mon''⎕NA''', fn, '>PP P <PP''  ⋄ '
             f, '0=⎕NC''α'':mon 0 0 ω ⋄ dya 0 α ω} ⋄ 0'}
```

```
cio  ← {' -o ''',BUILD∆PATH,'/',⍵,'_',⍺,'.',⍺⍺,''' '}
fls  ← {'''',BUILD∆PATH,'/',⍵,'_',⍺,'.cpp'' '}
log  ← {'> ',BUILD∆PATH,'/',⍵,'_',⍺,'.log 2>&1'}
lib  ← {'-l',AF∆LIB,' '}
cci  ← {'-I''',AF∆PREFIX,'/include'' -L''',AF∆PREFIX,'/lib'' '}
cco  ← '-std=c++11 -Ofast -g -Wall -fPIC -shared'
ucc  ← {⎕SH ⍺⍺,' ',cco,(cci ⍬),COMPILER (⍵⍵ cio,fls,lib,log) ⍵}
gcc  ← 'g++' ucc 'so'
clang ← 'clang++' ucc 'dylib'
vsco ← {z  ← '/W3 /wd4102 /wd4275 /Gm- /O2 /Zc:inline /Zi /Fd"',BUILD∆PATH
        z ,← '\vc.pdb" /errorReport:prompt /WX- /MD /EHsc /nologo '
             z,'/I"%AF_PATH%\include" /D "NOMINMAX" /D "AF_DEBUG" '}
vslo ← {z  ← '/link /DLL /OPT:REF /INCREMENTAL:NO /SUBSYSTEM:WINDOWS '
        z ,← '/LIBPATH:"%AF_PATH%\lib" /DYNAMICBASE "',AF∆LIB,'.lib" '
             z,'/OPT:ICF /ERRORREPORT:PROMPT /TLBID:1 '}
vsc0 ← {'"""',VISUAL∆STUDIO∆PATH,'\vcvarsall.bat" amd64'}
vsc1 ← {' && cd "',(⊃⎕CMD 'echo %CD%'),'" && cl ',(vsco ⍬),'/fast '}
vsc2 ← {'/Fo"',BUILD∆PATH,'\\" "',BUILD∆PATH,'\',⍵,'_vsc.cpp" '}
vsc3 ← {(vslo ⍬),'/OUT:"',BUILD∆PATH,'\',⍵,'_vsc.dll" '}
vsc4 ← {'> "',BUILD∆PATH,'\',⍵,'_vsc.log"""'}
vsc  ← {⎕CMD ('%comspec% /C ',vsc0,vsc1,vsc2,vsc3,vsc4) ⍵}

get  ← {⍺⍺ ⌷ ⍉⍵}
wrap ← ⍪∘(⍉ (1 + 1 ↑ ⍉) ⍪ 1 ↓ ⍉)
bind ← {n _ e ← ⍵ ⋄ (0 n_ ⌷ e) ← ⊂n ⋄ e}
at   ← {⍺ ← ⊢ ⋄ A ⊣ ((,B) ⌿ (r A) ⍴ A) ← ⍺ ⍺⍺ (,B) ⌿ ((r ← (≢⍴ B ← ⍵⍵ ⍵) ((×/ ↑) , ↓) ⍴) A) ⍴ (A ← ⍵)}

d_ t_ k_ n_ r_ s_ g_ v_ y_ e_ l_ ← ⍳ 7 + f∆ ← 4
d ← d_ get ⋄ t ← t_ get ⋄ k ← k_ get ⋄ n ← n_ get ⋄ r ← r_ get ⋄ s ← s_ get
g ← g_ get ⋄ v ← v_ get ⋄ y ← y_ get ⋄ e ← e_ get ⋄ l ← l_ get

new ← {⍉⍪ f∆ ↑ 0 ⍺, ⍵}                          ⋄ msk ← {(t ⍵) ∊ ⊂⍺⍺} ⋄ sel ← {(⍺⍺ msk ⍵)⌿ ⍵}
  A ← {('A' new ⍺⍺) wrap ⊃⍪/ ⍵}                  ⋄ Am ← 'A' msk        ⋄ As ← 'A' sel
  E ← {('E' new ⍺⍺) wrap ⊃⍪/ ⍵}                  ⋄ Em ← 'E' msk        ⋄ Es ← 'E' sel
  F ← {('F' new ⍺⍺) wrap ⊃⍪/ (⊂ 0 f∆ ⍴ ⍬), ⍵}    ⋄ Fm ← 'F' msk        ⋄ Fs ← 'F' sel
  G ← {('G' new 0) wrap ⊃⍪/ ⍵}                   ⋄ Gm ← 'G' msk        ⋄ Gs ← 'G' sel
  L ← {('L' new 0) wrap ⊃⍪/ ⍵}                   ⋄ Lm ← 'L' msk        ⋄ Ls ← 'L' sel
  M ← {('M' new 0 '') wrap ⊃⍪/ (⊂ 0 f∆ ⍴ ⍬), ⍵}  ⋄ Mm ← 'M' msk        ⋄ Ms ← 'M' sel
  N ← {'N' new 0 (⍎⍵)}                           ⋄ Nm ← 'N' msk        ⋄ Ns ← 'N' sel
  O ← {('O' new ⍺⍺) wrap ⊃⍪/ ⍵}                  ⋄ Om ← 'O' msk        ⋄ Os ← 'O' sel
  P ← {'P' new 0 ⍵}                              ⋄ Pm ← 'P' msk        ⋄ Ps ← 'P' sel
  S ← {'S' new 0 ⍵}                              ⋄ Sm ← 'S' msk        ⋄ Ss ← 'S' sel
  V ← {'V' new ⍺⍺ ⍵}                             ⋄ Vm ← 'V' msk        ⋄ Vs ← 'V' sel
  Y ← {'Y' new 0 ⍵}                              ⋄ Ym ← 'Y' msk        ⋄ Ys ← 'Y' sel
  Z ← {'Z' new 1 ⍵}                              ⋄ Zm ← 'Z' msk        ⋄ Zs ← 'Z' sel
```

```
     _o ← {0 ≥ ⊃ c a e r ← p ← α αα ω : p ⋄ 0 ≥ ⊃ c a e r2 ← p ← α ωω ω : p ⋄ c a e (r ↑⍨ - ⌊/ ≢¨ r r2)}
     _s ← {0 < ⊃ c a e r ← p ← α αα ω : p ⋄ 0 < ⊃ c2 a2 e r ← p ← e ωω r : p ⋄ (c ⌈ c2)(a, a2) e r}
 _noenv ← {0 < ⊃ c a e r ← p ← α αα ω : p ⋄ c a α r}
   _env ← {0 < ⊃ c a e r ← p ← α αα ω : p ⋄ c a (e ωω a) r}
  _then ← {0 < ⊃ c a e r ← p ← α αα ω : p ⋄ 0 < ⊃ c a e _ ← p ← e (ωω _s eot) a : p ⋄ c a e r}
   _not ← {0 < ⊃ c a e r ← α αα ω : 0 a α ω ⋄ 2 a α ω}
    _as ← {0 < ⊃ c a e r ← α αα ω : c a e r ⋄ c (,⊂ωω a) e r}
     _t ← {0 < ⊃ c a e r ← α αα ω : c a e r ⋄ e ωω a : c a e r ⋄ 2 θ α ω}
   _ign ← {c a e r ← α αα ω ⋄ c θ e r}
  _peek ← {0 < p ← ⊃ α αα ω : p ⋄ 0 θ α ω}
   _yes ← {0 θ α ω}
   _opt ← {α(αα _o _yes)ω}
   _any ← {α(αα _s ∇ _o _yes)ω}
  _some ← {α(αα _s (αα _any))ω}
   _set ← {(0 ≠ ≢ω) ∧ (⊃ω) ∊ αα : 0 (,⊃ω) α (1 ↓ ω) ⋄ 2 θ α ω}
    _tk ← {((≢,αα) ↑ ω) ≡,αα : 0 (⊂,αα) α ((≢,αα) ↓ ω) ⋄ 2 θ α ω}
   _eat ← {0 = ≢ω : 2 θ α ω ⋄ 0 (αα ↑ ω) α (αα ↓ ω)}

     ws ← (' ', ⎕UCS 9) _set
    aws ← ws _any _ign
  awslf ← (⎕UCS 10 13) _set _o ws _any _ign
   gets ← aws _s ('←' _tk) _s aws
    him ← '¯' _set
    dot ← '.' _set
    jot ← '∘' _set
   lbrc ← aws _s ('{' _set) _s aws
   rbrc ← aws _s ('}' _set) _s aws
   lpar ← aws _s ('(' _tk) _s aws _ign
   rpar ← aws _s (')' _tk) _s aws _ign
   lbrk ← aws _s ('[' _tk) _s aws _ign
   rbrk ← aws _s (']' _tk) _s aws _ign
    grd ← aws _s (':' _tk) _s aws _ign
   egrd ← aws _s ('::' _tk) _s aws _ign
  alpha ← 'ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz∆' _set
 digits ← '0123456789' _set
   prim ← (prims ← '+-÷×|*⍟⌈⌊!<≤=≠≥>∧∨⍲⍱⌷?⍴,⍪⌽⊖⍉∊⍷⊃⍳○~≡≢⊢⊣/⌿\⍀⊤⊥↑↓∪∩⍋⍒∇⌹') _set
    mop ← '¨/⌿⍀\⍨' _set
   dop1 ← '.⍣∘' _set
   dop2 ←'⍤⍣∘' _set
   dop3 ←'∘' _set
    eot ← aws _s {'' ≡ ω : 0 θ α '' ⋄ 2 θ α ω} _ign
   digs ← digits _some
  odigs ← digits _any
    int ← aws _s digs _s (him _opt) _s aws
  float ← aws _s (odigs _s dot _s int _o (digs _s dot)) _s aws
   name ← aws _s (alpha _o (digits _some _s alpha) _some) _s aws
     aw ← aws _s ('αω' _set) _s aws
   aaww ← aws _s (('αα' _tk) _o ('ωω' _tk)) _s aws
    sep ← aws _s (('⋄', ⎕UCS 10 13) _set _ign) _s aws
    nss ← awslf _s (':Namespace' _tk) _s aws _s (name _opt) _s awslf _ign
    nse ← awslf _s (':EndNamespace' _tk) _s awslf _ign
```

```
  Sfn ← aws _s (('TFF⎕' _tk) _o ('TFFI⎕' _tk)) _s aws _as {P ⌽∊ω}
 Prim ← prim _as P
   Vt ← {((0 ⌷ ⍉α) ⍳ ω) 1 ⌷ α ⍪ '' ¯1}
  Var ← {α(aaww _o aw _o (name _as ⌽) _t (αα = Vt) _as (ωω V∘,∘⊃))ω}
  Num ← float _o int _as (N∘⌽)
Strand ← 0 Var 'a'  _s (0 Var 'a' _some) _as ('s' A∘⌽)
  Pex ← {α(rpar _s Ex _s lpar)ω}
 Atom ← Strand _o (0 Var 'a' _as ('v'A)) _o (Num _some _as ('n' A∘⌽)) _o Pex
  Idx ← {α(rbrk _s Ex _s lbrk _s Atom _as ('i' E∘⌽))ω}
 Blrp ← {α(αα _s (ωω Slrp ∇))ω}
 Slrp ← {α(αα _o (ωω _s ∇) _o ((1 _eat) _s ∇))ω}
   Fa ← {                        e ← ('ωω' 'αα', 'αω') ,∘⍪⍤1 ⍉ ¯1 + 3 3 2 2 ⊤ (6 4 4 ⌿ 1 5 9) + 2 × ⍳ 14
                                 a ← e (α{ω Gex _o Ex _o Fex Stmts _then Fn⍨ αα ⍪ α})⍤2 1 ⊢ ω
                                 m ← (0 = 0 ⌷ ⍉a) ∧ ∧⌿ (∨⍀ ∘.=⍨ ⍳14) ∨ ∘.≢⍨ 1 ⌷ ⍉a
                            ~∨⌿ m  :  (⌈⌿ 0 ⌷ ⍉a) ⊖ α ω
          (1 = +⌿ m) ∧ 2 > m ⍳ 1  :  0 (,⊂('F' new 1) wrap ⊃⊃ m ⌿ 1 ⌷ ⍉a) α ω
                                 z ← ('F' new 'a') wrap ⊃ (m ⌿ 'F' new¨ 1 + ⍳14) ⍪.(wrap∘⊃) m ⌿ 1 ⌷ ⍉a
                                     0 (,⊂z) α ω}
   Fn ← {                       ns ← n z ⌿⍨ m ← {(F_m ω) ∧ ¯1 ∊⍨ k ω} z ← ⊃⍪/ ω ⋄ 0 = ≢ns : 0 (,⊂z) α ''
                                 p ← α∘Fa¨ ns ⋄ 0 < c ← ⌈/ ⊃¨p : c ⊖ α ω
                                     0 (⍪/ (⊂ 0 4 ⍴ ⊖) ,⍨ p {ω ((d +∘⊃ ⊣), 1 ↓⍤1 ⊢) ⊃⍪/ 1 ⊃ α}¨at{m} ↓z) α ''}
  Pfe ← {α(rpar _s Fex _s lpar)ω}
  Bfn ← rbrc Blrp lbrc _as ('F' new ¯1 ,∘⊂∘⌽ 1 ↓ ¯1 ↓ ⊢)
  Fnp ← Prim _o (1 Var 'f') _o Sfn _o Bfn _o Pfe
  Mop ← {α((mop _as P) _s Afx _as (1 O))ω}
 Dop1 ← {α((dop1 _as P) _s Afx _as (2 O∘⌽))ω}
 Dop2 ← {α(Atom _s (dop2 _as P) _s Afx _as (2 O∘⌽))ω}
 Dop3 ← (dop3 _as P) _s Atom _as (2 O∘⌽) _o (dot _s jot _as (P∘⌽) _as (1 O))
  Bop ← {α(rbrk _s Ex _s lbrk _s Afx _as ('i' O∘⌽))ω}
  Afx ← Mop _o (Fnp _s (Dop1 _o Dop3 _opt) _as (⊃wrap/∘⌽)) _o Dop2 _o Bop
  Trn ← {α(Afx _s ((Afx _o Idx _o Atom) _s (∇ _opt) _opt))ω} _as ('t' F∘⌽)
 Bind ← {α(gets _s (name _as ⌽) _env (αα{(⊃⌽ω) αα ⍪ α}) _as (ωω new 'b', 1 ↓ ⊢))ω}
  Fex ← Afx _s (Trn _opt) _s (1 Bind 'F' _any) _as (⊃wrap/∘⌽)
  App ← Afx _s (Idx _o Atom _s (dop2 _not) _opt) _as {(≢ω) E ⌽ω}
   Ex ← Idx _o Atom _s {α(0 Bind 'E' _o App _s ∇ _opt)ω} _as (⊃wrap/∘⌽)
  Gex ← Ex _s grd _s Ex _as (G∘⌽)
 Nlrp ← sep _o eot Slrp (lbrc Blrp rbrc)
Stmts ← {α(sep _any _s (Nlrp _then (αα _s eot∘⌽)) _any _s eot)ω}
   Ns ← nss Blrp nse _then (Ex _o Fex Stmts _then Fn) _s eot _as M

   ps ← {0 ≠ ⊃ c a e r ← (0 2 ⍴ ⊖) Ns ∊{ω /⍨ ∧\ '⍝' ≠ ω}¨ω ,¨ ⎕UCS 10 : ⎕SIGNAL c ⋄ (⊃a) e}
```

```
scp  ← (+⍀ F_m) ⊢∘⊂⌸ ⊢
prf  ← ((≢ ↑ ¯1 ↓ ⊢ (⌿⍨) 0 ≠ ⊢)⍤1 ↑∘r) ⊢
blg  ← {α ← ⊢ ⋄ α((prf (⌈/ (ι∘≢⊢) ×⍤1 (1 ↓ ⊣) ∧.(= ∨ 0 = ⊢)∘⍉ ⊢) αα (⌿∘↑) r)⌷⍤0 2 ωω (⌿⍨) αα)ω}
enc  ← ⊂ ⊣ ,∘⊃ ((⊣, '_', ⊢)/ (⊂''), (⍕¨ ⊢ (/⍨) 0 ≠ ⊢))
veo  ← ∪ ((⊂'%u'), (,¨prims), ⊣) ~⍨∘{⊃,/ {⊂⍣(1 ≡ ≡ω) ⊢ ω}¨ω} ¯1 ↓ ⊢ (/⍨) (∧/¨ 0 ≠ ((⊃ 0 ρ ⊢)¨⊢))
ndo  ← {α ← ⊢ ⋄ m ⊃∘(⊂, ⊢)¨ α∘αα¨¨ ω ⊃∘(,∘⊂⍨⊂)¨⍨ m ← 1 ≥ ≡¨ω}
n2f  ← (⊃,/) ((1 = ≡) ⊃ ,∘⊂⍨∘⊂)¨

rn   ← ⊢ ,∘↓ (1 + d) ↑⍤¯1 (+⍀ d ∘.=∘ι 1 + (⌈/ 0, d))
rd   ← ⊢ , (+/ ↑∘r ∧.(= ∨ 0 = ⊢)∘⍉∘↑∘r ⊢ (⌿⍨) F_m ∧ 1 ∊⍨ k)
df   ← ⊢ (⌿⍨) (+\ 1 = d) (~ ⊣ ∊ ⊣ (/⍨) (1 = d) ∧ (~ 'b' ∊⍨ k) ∧ O_m ∨ F_m) ⊢
dua  ← ((~G_m) ∧ F_m ∨ ↓∘prf ∊ r∘F_s) (⊣ (⍀∘⊢) (d (⌿⍨) ⊣) (0, 1 ↓ (¯1 ⌽ ⊢) ∧ ⊣ = ¯1 ⌽ ⊣) ⊣ (⌿∘⊢) 0 ∊⍨ n) ⊢
du   ← ⊢ (⌿⍨∘~) dua ∨∘(∨/) (prf ∧.(= ∨ 0 = ⊢)∘⍉ prf (⌿⍨) dua) ∧ ↑∘r ∧.≥∘⍉ dua (⌿∘⊢) ↑∘r × 0 = prf
lfh  ← (0 ≠ 1 ⌷ ⊣) ⊃ (⊂∘⍉∘⍪ 0 'M' 0 '', 0 ,⍨ (⊂⊣)) ,∘⊂∘⍉∘⍪ 1 'F' 1, ('fn' enc ⊣), (⊂⊣), 5 ↓∘, 1 ↑ ⊢
lfn  ← (d, 'Of', 3 ↓ ⊢)⍤1 at (F_m ∧ 'b' ∊⍨ k) (d, 'Vf', ('fn' enc∘⊃ r), 4 ↓ ⊢)⍤1 at (F_m ∧ 1 ∊⍨ k)
lf   ← (⊃⍪/) (1, 1 ↓ F_m ∧ 1 ∊⍨ k) blg (↑r) (⊂ lfh ⍪∘(((⊢ - (⊃ - 2 ⌊ ⊃)) d), 1 ↓⍤1 ⊢) lfn)⌸ 1 ↓ ⊢
dn   ← ((0 ∊⍨ n) ∧ (A_m ∧ 'v' ∊⍨ k) ∨ O_m ∧ 'f' ∊⍨ k) ((~⊣) (⌿∘⊢) (d - ¯1 ⌽ ⊣), 1 ↓[1] ⊢) ⊢
mrep ← (1 + ⊃), 'P' 0 (,'⊢'), (⊂'') ,⍨ ¯1 ↓ 4 ↓∘, 1 ↑ ⊢
mreu ← ⊃, 'E' 'u', (⊂'') ,⍨ ¯1 ↓ 3 ↓∘, 1 ↑ ⊢
mre  ← (⊃⍪/) (-∘⊃ V_m ∨ A_m)∘⊃∘⌽ (↓, (((⊢ ρ⍨ (≢⍉) ,⍨ ≢ × 2 < ≢) mreu ⍪ mrep ⍪ (1 + d), 1 ↓⍤1 ⊢)¨ ↑)) ⊢
mrs  ← ⊢ ⊂[0]⍨ 1, 1 ↓ d = 1 +∘⊃ d
mrk  ← (-∘(+/ ∧\)∘⌽ L_m) (↑ ⍪⍨∘(mre (mre mrs)¨ at (G_m∘(⊃⍪/) 1 ↑¨ ⊢)∘mrs) ↓) ⊢
mr   ← (⊃⍪/) ((1 ↑ ⊢), (mrk¨ 1 ↓ ⊢))∘scp
ur   ← ((2 ↑ ⊢), 1, ('um' enc∘⊃ r), 4 ↓ ⊢)⍤1 at (E_m ∧ 'u' ∊⍨ k)
rt   ← ⊢, (∨\ F_m) + (+⌿ prf ∧.(= ∨ 0 = ⊣)∘⍉⍨∘↑∘r M_s ⍪ G_s) - F_m
nm   ← ((3 ↑ ⊢), ('fe' enc∘⊃ r), 4 ↓ ⊢)⍤1 at ((0 ∊⍨ n) ∧ E_m ∨ O_m ∨ A_m)
lgg  ← (⍪/ 1 ↓ ⊢) ⍪∘⊃⍨ ⊣ (((¯1 + d), 2 ,⍨ t, k, n, r ,∘⍪ s) ⍪ ⊣ ⍪ 3, 'V', 'a', 3 (↓⍤1) 1 ↑ ⊢)∘⊃ 1 ↑ ⊢
lg   ← (⊃⍪/) ⊢ ((⊂ ⊣ (⌿⍨∘~) (∨\ ⊢)), (((1 ↑ ⊢) lgg ⊢ ⊂[0]⍨ d = 1 + ⊃)¨ ⊂[0]⍨)) G_m ∧ 1 ⌽ E_m
fet  ← (d, 'V' 0, 3 ↓ ⊢)⍤1 at (0, 1 ↓ E_m ∨ O_m ∨ A_m) (d, 'Av', 3 ↓ ⊢)⍤1 at (E_m ∧ 'b' ∊⍨ k)
fee  ← (⍪/⌽) (M_m ∨ E_m ∨ O_m ∨ A_m) blg ⊢ ((⊃∘⌽ ⊢) (⊂ (d - -⍨∘ ⊃), 1 ↓⍤1 ⊢)∘fet ⊣ ⍪ ¯1 ↓⍤1 ⊢)⌸ ⊃ ,⍨ 1 ↓ ⊢
fe   ← (⊃⍪/) (+⍀ d ≤ g) (⊂ (⊢ ↑⍨ 1 =∘≢ ⊢) ⍪∘⊃∘fee ⊢)⌸ ⊢
can  ← (+\ A_m ∨ O_m) ((, 1 ↑ ⊢) ,∘(⊂ (¯1 + 2 ⌊ ≢) ⊃ (⊂∘⊂ ⊃), ⊂)∘n 1 ↓ ⊢)⌸ ⊢
cas  ← (¯1 ⌽ (A_m ∨ O_m) ∧ 'vf' ∊⍨ k) ∨ (↓prf) ∊∘r ⊢ (⌿⍨) A_m ∧ 'n' ∊⍨ k
ca   ← (can ⊢ (⌿⍨) cas ∨ A_m ∨ O_m ∧ 'f' ∊⍨ k) ⊣ at (A_m ∨ O_m ∧ 'f' ∊⍨ k) ⍬ ,∘⊂⍨ ⊢ (⌿⍨∘~) cas
lj   ← (⊃⍪/) (1 ↑ scp), ((⊢ ⍪ 2 'L' 0 0, 2 '' ,⍨ ¯2 ↓ 4 ↓∘, 1 ↑ ⊢)¨ 1 ↓ scp)
sd   ← (⊃⍪/) (1 ↑ scp), (n F_s) (d, 'Vf', (⊂⊣), 4 ↓ ⊢)⍤1 at ((⊂, '∇') ∊⍨ n)¨ 1 ↓ scp
inm  ← ∨⌿ ¯1 (⌽ ∨ ⊢) 1 2 (⌽ ∨ ⊢) (¯1 ¯2 ⌽ E_m ∧[1] 1 2 ∘.= k) ∧⍤1 V_m ∧ n ∊∘n F_s
inp  ← (E_m ∧ ⊣) ∨ 1, 2 ≠/ ⊣
inza ← (1 ↑ 1 ↓ ⊣) (⌿⍨∘≢) at ((⊂, 'α') ∊⍨ n) (¯1 ↑ ⊣) (⌿⍨∘≢) at ((⊂, 'ω') ∊⍨ n) ⊢
inz  ← (1 ↑ ⊣) (d, t, k, 3 ↓⍤1 (⌿⍨∘≢)) at (0 ,⍨ 2 ≠/∘⌽ (∨\∘⌽ E_m)) inza
inn  ← (3 ↑⍤1 ⊢), ((⊣ ρ¨⍨ 1 + 0 ⌈ (⌈/∘n G_s)) (('fe' ≡ 2 ↑ ⊢) ⊃ (⊂⊢) ,∘⊂ 'fe', (⍕⊣), 2 ↓ ⊢)¨ n), (4 ↓⍤1 ⊢)
ins  ← ⊣ (d, t, k, ((1000 × 1 + ⊣) + 1 + n + (⌈/n)), 4 ↓⍤1 ⊢) at (L_m ∨ G_m) inn
inr  ← 1 ,∘⍪ ⊢ inz¨ (ι∘≢ ⊢) ins¨ ((⊃∘n¨ ⊣) ι ((⊃ n (⌿⍨) V_m ∧ 'f' ∊⍨ k)¨ ⊢)) ⊃¨ (⊂ 1 ↓¨ ⊣) ,∘⊂¨ ⊢
in   ← (⊃⍪/)∘(⊢/) (1 ↓ scp) inr∘((0 ρ ⊂ 0 8 ρ 0), ⊢/) at (⊣/) inm ((⊃¨ inp ⊂ E_m ∧ ⊣) ,∘⍪ inp ⊂[0] ⊢) ⊢
```

```
pcc ← (⊂⊢(≠⍨) A_m ∨ O_m ∧ 'f' ∊⍨ k)∘((⍳∘∪⍨ n) ⌷⍤0 2 (1 ⌈ ≢) ↑ ⊢)∘(⊃⍪≠)∘⌽ (≠∘⊢)
pcb ← ((, ∧.(= ∨ 0 = ⊣)∘⍪)⍤2 1⍨∘↑∘r M_s ⍪ F_s) pcc⍤1 ((⊢ (≠⍨) (d = g) ∧ A_m ∨ E_m ∨ O_m)¨ scp)
pcv ← (d, 'V', ('af' ⊃¨∘⊂⍨ O_m), (⊃¨v), r, s, (⊂θ) ,⍨∘⍪ g) at (O_m ∨ A_m ∧ 'v' ∊⍨ k)
pc ← (⊃⍪/) pcb {(pcv d (⊣, 1 ↓⍤1 ⊢)(α ↑⍨ 1 ⌈ ≢α) ⌷⍤0 2⍨ (n α) ι n) at (V_m ∧ (n α) ∊⍨ n) ω}¨ scp
da ← ⊢ (≠⍨∘~) (A_m ∧ d = g) ∨ (0 ,⍨ 2 ∧/ L_m) ∨ (L_m ∧ ¯1 ⌽ A_m ∧ d = g) ∨ O_m ∧ ('f' ∊⍨ k) ∧ 1 ≠ d
fce ← (⊃∘n P_s) {⊂⍎ 'ω' ,⍨ (≢ω) ⊃ '' (α, '⊃') ('⊃', α, '/')} (v A_s)
fcm ← (∧/ E_m ∨ A_m ∨ P_m) ∧ 'u' ≢∘⊃∘⊃ k
fc ← ((⊃⍪/) (((d, 'An', 3 ↓ ¯1 ↓ ,) 1 ↑ ⊢), fce)¨ at (fcm¨)) ('MFOEL' ∊⍨ t) ⊂_[0] ⊢
ce ← (+\ F_m ∨ G_m ∨ E_m ∨ O_m ∨ L_m) ((¯1 ↓∘, 1 ↑ ⊢) ,∘⊂ (⊃∘v 1 ↑ ⊢) ,∘(A_m ⊃¨∘↓ n ,∘⍪∘n2f v) 1 ↓ ⊢)⌸ ⊢
ll ← (⊢ (≠⍨) 1 ⌽ L_m) (((⊂⊂'%l') ,∘⊂¨∘n ⊣) ,⍨ ¯1 ↓⍤1 ⊢) at L_m ⊢
fv ← (⊃⍪/) (((1 ↓ ⊢) ⍪⍨ (, 1 7 ↑ ⊢) ,∘⊂∘n ¯1 ↑ ⊢)¨ scp)
nvi ← ((¯1 ↓ ⊢), ({,¨ α '[' ω}/∘⊃ v))⍤1 at ((E_m ∨ O_m) ∧ 'i' ∊⍨ k)
nvv ← (⊂'%u' '%f' '%u'), (⊂ '%u' '%i', ⊢), (⊂ (⊂'%u'), ⊢)
nv ← (¯1 ↓⍤1 ((2 ↑ ⊢), 2, (3 ↓ ⊢))⍤1 at ((E_m ∨ O_m) ∧ 'i' ∊⍨ k)), ((¯1 ⊖ ≢ ⊃ nvv ,∘⊂ ⊢)¨ v∘nvi)
lt ← (⊂θ) ,⍨ ⊢
val ← (n ⍳∘∪ n) ,¨ ⊢ (⊢ + (≢⊣) × 0 = ⊢) (⌈/ (⍳≢) ×⍤1 (∪n) ∘.((⊂⊣) ∊ ⊢) (n2f¨ v))
vag ← ∧∘~∘(∘.=⍨∘⍳ ≢)⍨ (∘.(((1 ⌷ ⊢) > 0 ⌷ ⊣) ∧ (0 ⌷ ⊢) < 1 ⌷ ⊣)⍨ val)
vae ← (∪n) (⊣ ,⍤0 ⊣ (⌷⍨⍤1 0)∘⊃ ((⊢ ,∘⊃ (⍳∘≢ ⊣) ~ ⊢ (≠⍨) (≢⊢) ↑ ⊣)/∘⌽ (⊂θ) ,∘↓ ⊢)) vag
vac ← (((0 ⌷∘⍉ ⊣) ⍳∘⊂ ⊢) ⊃ (1 ⌷∘⍉ ⊣) ,∘⊂ ⊢) ndo
va ← ((⊃⍪/) (1 ↑ ⊢), (((vae E_s) (d, t, k, (⊣ vac n), r, s, g, y ,∘⍪⍨ (⊂⊣) vac¨ v) ⊢)¨ 1 ↓ ⊢)) scp
avb ← {((((,¨'αω') ↑⍨ 1 ↓ ρ) ⍪ ⊢) α ⌷⍨⍤2 0 ⊢ αα ι αα ∩⍨ (↓ (⌽ 1 +∘ι 0 ι⍨ ⊢) ((≢⊢) ↑ ↑)⍤0 1 ⊢) ⊃ r ω}
avi ← ¯1 0 + (ρ⊣) ⊤ (,⊣) ι (⊂⊢)
avh ← {⊂ ω, (nω) ((αα (ωω avb) ω) {αα avi ndo (⊂α), ω})¨ v ω}
av ← (⊃⍪/) (+\ F_m) {α((α ((∪∘⌽ (0 ρ ⊂''), n) E_s)⌸ ω) avh (r (1 ↑ ω) ⍪ F_s ω))⌸ ω} ⊢
rlf ← (⌽ ↓ (((1 ⊃ ⊣) ∪ ⊢ ~ 0 ⌷ ⊣)/∘⌽ (⊂θ), ↑)⍤0 1⍨ 1 +∘ι ≢) (⊖ 1 ⊖ n ,⍤0 (⊂⊣) veo¨ v)
rl ← ⊢ ,∘(⊃,/) (⊂∘n O_s ⍪ F_s) rlf¨ scp
vc ← (⊃⍪/) (((1 ↓ ⊢) ⍪⍨ (1 7 ↑ ⊢), (≢∘∪∘n E_s), 1 ¯3 ↑ ⊢)¨ scp)
eff ← (⊃⍪/) ⊢ (((⊂∘⍉∘⍪ d, 'Fe', 3 ↓ ,) 1 ↑ ⊣), 1 ↓ ⊢) (d =∘⊃ d) ⊂_[0] ⊢
ef ← (F_m ∧ ¯1 =∘×∘⊃¨ y) ((⊃⍪/) (⊂ ⊢ (≠⍨)∘~ (∨\ ⊣)), (eff¨ ⊂_[0])) ⊢
ifn ← 1 'F' 0 'Init' θ 0 1, (4 ρ 0) θ θ ,⍨ ⊢
if ← (1 ↑ ⊢) ⍪ (⊢ (≠⍨) O_m ∧ 1 = d) ⍪ ((⊢ wrap⍨∘ifn∘≢∘∪ n) ⊢ (≠⍨) E_m ∧ 1 = d) ⍪ (∨\ F_m) (≠∘⊢) ⊢
fgz ← (1 ↑ ⊢) ⍪ (((¯1 + d), 1 ↓⍤1 ⊢) 1 ↓ ⊢) ⍪ 2, 'G', 1, 3 ↓⍤1 (¯1 ↑ ¯1 ↓⍤1 ⊢) ,∘n 1 ↑ ⊢
fg ← (⊃⍪/) (fgz¨ at (G_m∘(⊃⍪/) 1 ↑¨ ⊢) ⊢ ⊂_[0]⍨ d = 2 ⌊ g)
fft ← (, 1 ↑ ⊢) (1 'Z', (2 ↓ ¯5 ↓ ⊣), (v⊣), n, y, (⊂ 2 ↑∘,∘⊃∘⊃ e), l) (¯1 ↑ E_s)
ff ← ((⊃⍪/) (1 ↑ ⊢), (((1 ↑ ⊢) ⍪ (((¯1 + d), 1 ↓⍤1 ⊢) 1 ↓ ⊢) ⍪ fft)¨ 1 ↓ ⊢)) scp
fzh ← ((∪n) ∩ (⊃∘l ⊣)) (¯1 ⌽ (⊂⊣), ((≢⊢) - 1 + (⌽n) ι ⊣) ((⊂ ⊣ ⊃¨∘⊂ (⊃¨e)), (⊂ ⊣ ⊃¨∘⊂ (⊃¨y)) ,∘⊂ ⊣) ⊢) ⊢
fzf ← 0 ≠ (≢∘ρ¨∘⊃∘v ⊣)
fzb ← (((⊃∘v ⊣) (≠⍨) fzf), n) ,∘⍪ ('f'∘,∘⍕¨∘ι (+/fzf)), ('s'∘,∘⍕¨∘ι∘≢ ⊢)
fzv ← ((⊂⊣) (⊖↑)⍨¨ (≢⊣) (- +∘ι ⊢) (≢⊢)) ((⊢ ,⍨ 1 ⌷∘⍉ ⊣) ⌷⍨ (0 ⌷∘⍉ ⊣) ι ⊢)⍤2 0¨ v
fze ← (¯1 + d), t, k, fzb ((⊢/ (-∘≢ ⊢) ↑ ⊣), r, s, g, fzv, y, e ,∘⍪ l) ⊢
fzs ← (, 1 ↑ ⊢) (1 ⊖ (⊣ ((1 'Y', (2 ⌷ ⊣), ⊢) ⍪∘⍉∘⍪ (3 ↑ ⊣), ⊢) 1 ⌽ fzh, ¯1 ↓ 6 ↓ ⊣) ⍪ fze) (≠∘⊢)
fz ← ((⊃⍪/) (1 ↑ ⊢), (((2 = d) (fzs ⍪ (1 ↓∘~ ⊣) (≠∘⊢) 1 ↓ ⊢) ⊢)¨ 1 ↓ ⊢)) (1, 1 ↓ S_m) ⊂_[0] ⊢
fd ← (1 ↑ ⊢) ⍪ ((1, 'Fd', 3 ↓ ⊢)⍤1 F_s) ⍪ 1 ↓ ⊢

tta ← (fc∘da∘(pc⍣≡)∘mr⍣≡)∘in⍣3∘sd∘lj∘ca∘fe∘lg∘nm∘rt∘mr∘dn∘lf∘du∘df∘rd∘rn
tt ← fd∘fz∘ff∘fg∘if∘ef∘vc∘rl∘av∘va∘lt∘nv∘fv∘ll∘ce∘ur∘tta
```

```
 E₁ ← {'fn' gcl ((⊂ n ,∘⊃ v), e, y) ω}
 E₂ ← {'fn' gcl ((⊂ n ,∘⊃ v), e, y) ω}
 E₀ ← {r l f ← ⊃ v ω ⋄ (n ω) ((⊃ y ω) sget) (¯1 ↓ ⊃ y ω) (f scal sdb) r l}
 O₁ ← {'op' gcl ((⊂ n ,∘⊃ v), e, y) ω}
 O₂ ← {'op' gcl ((⊂ n ,∘⊃ v), e, y) ω}
 O₀ ← {''}
 O_f ← {'EF(', ('∆' ⎕R '__' ⊃ n ω), ',', (⊃⊃ v ω), ');', nl}
 F_d ← {'FP(', (⊃ n ω), ');', nl}
 F₀ ← {'DF(', (⊃ n ω), '_f){', nl, 'A*env[]={tenv};', nl}
 F₁ ← {'DF(', (⊃ n ω), '_f){', nl, ('env0' dnv ω), (fnv ω)}
 G₀ ← {v ← (⊃⊃ v ω) ('' var) 1 ⊃ ⊃ e ω
        'if(1!=cnt(', v, '))err(5);if(', v, '.v.as(s32).scalar<I>()){', nl}
 G₁ ← {'z=', ((⊃ n ω) ('' var) ⊃ ⊃ e ω), ';goto L', (⍕⊃ l ω), ';}', nl}
 L₀ ← {'z=', a, ';L', (⍕⊃ n ω), ':', (a ← (1 ⊃ ⊃ v ω) ('' var) 1 ⊃ ⊃ e ω), '=z;', nl}
 Z₀ ← {'}', nl, nl}
 Z₁ ← {'}', nl, nl}
 Z_e ← {'}', nl, nl}
 M₀ ← {rth, ('tenv' dnv ω), nl, 'A*env[]={', ((0 ≡ ⊃ω) ⊃ 'tenv' 'NULL'), '};', nl, nl}
 S₀ ← {(('{', rk0, srk, 'DO(i,prk)cnt*=sp[i];', spp, sfv, slp) ω)}
 Y₀ ← {⊃,/ ((⍳ ≢ ⊃ n ω) ((⊣ sts¨ (⊃l) ,¨∘⊃ s), '}', nl, ⊣ ste¨ (⊃n) var¨∘⊃ r) ω), '}', nl}

gc ← {⊃,/ {0 = ⊃ t ω : ⊂ 5 ρ ⍬ ⋄ ⊂ (⍎ (⊃ t ω), ⍕ ⊃ k ω) ω}⍤1 ⊢ ω}

 syms  ←,¨ '+'   '-'   '×'   '÷'   '*'   '⍟'   '|'   '○'   '⌊'   '⌈'   '!'
 nams  ←   'add' 'sub' 'mul' 'div' 'exp' 'log' 'res' 'cir' 'min' 'max' 'fac'
 syms ,←,¨ '<'   '≤'   '='   '≥'   '>'   '≠'   '~'   '∧'   '∨'   '⍲'   '⍱'
 nams ,←   'lth' 'lte' 'eql' 'gte' 'gth' 'neq' 'not' 'and' 'lor' 'nan' 'nor'
 syms ,←,¨ '⌷'   '['   '⍳'   'ρ'   ','   '⍪'   '⌽'   '⍉'   '⊖'   '∊'   '⊃'
 nams ,←   'sqd' 'brk' 'iot' 'rho' 'cat' 'ctf' 'rot' 'trn' 'rtf' 'mem' 'dis'
 syms ,←,¨ '≡'   '≢'   '⊢'   '⊣'   '⊤'   '⊥'   '/'   '⌿'   '\'   '⍀'   '?'
 nams ,←   'eqv' 'nqv' 'rgt' 'lft' 'enc' 'dec' 'red' 'rdf' 'scn' 'scf' 'rol'
 syms ,←,¨ '↑'   '↓'   '¨'   '⍨'   '.'   '⍤'   '⍣'   '∘'   '∪'   '∩'
 nams ,←   'tke' 'drp' 'map' 'com' 'dot' 'rnk' 'pow' 'jot' 'unq' 'int'
 syms ,←,¨ '⍋'   '⍒'   '∘.'  '⍷'   '⊂'   '⌹'   '⎕FFT' '⎕IFFT' '%u'
 nams ,←   'gdu' 'gdd' 'oup' 'fnd' 'par' 'mdv' 'fft' 'ift' ''

 nl ← ⎕UCS 13 10 ⋄ fvs ← ,⍤0 (⌿⍨) 0 ≠ (≢∘ρ¨ ⊣) ⋄ cln ← '¯' ⎕R '-' ⋄ cnm ← (syms ⍳ ⊂) ⊃ (nams, ⊂)
 lits ← {'A(0,eshp,constant(', (cln ⍕ ω), ',eshp,', ('f64' 's32' ⊃⍨ ω = ⌊ω), '))'}
 litv ← {'std::vector<', ('DI' ⊃⍨ ∧/ ω = ⌊ω), '>{', (cln ⊃ {α, ',', ω}/ ⍕¨ ω), '}.data()'}
 lita ← {'A(1,dim4(', (⍕≢ω), '),array(', (⍕≢ω), ',', (litv ω), '))'}
 lit ← {' ' = ⊃ 0 ρ ω : (cnm ω), α ⋄ 1 = ≢ω : lits ω ⋄ lita ω}
 var ← {α ≡ ,'⍺' : ,'l' ⋄ α ≡ ,'⍵' : ,'r' ⋄ ¯1 ≥ ⊃ω : αα lit ,α ⋄ 'env[', (⍕⊃ω), '][', (⍕⊃ ⌽ω), ']'}
 dnv ← {(0 ≡ z) ⊃ ('A ', α, '[', (⍕ z ← ⊃ v ω), '];') ('A*', α, '=NULL;')}
 fnv ← {z ← 'A*env[', (⍕ 1 + ⊃ s ω), ']={', (⊃,/ (⊂'env0'), {',p[', (⍕ω), ']'}¨ ⍳ ⊃ s ω), '};', nl}
 gcl ← {z r l n ← ((3 ρ ⊂'fn'), ⊂α) {⊃ α var/ ω}¨ ↓ (⊃ω), ⍪ 1 ⊃ ω ⋄ n, '(', (⊃{α, ',', ω}/ z l r ~ ⊂'fn'), ',env);', nl}
```

```
∇Z ← Gfx∆Init S
  'w_new'   ⎕NA 'P  ', (BSO S), '|w_new <C[]'
  'w_close' ⎕NA 'I  ', (BSO S),'|w_close P'
  'w_del'   ⎕NA (BSO S), '|w_del P'
  'w_img'   ⎕NA (BSO S), '|w_img <PP P'
  'w_plot'  ⎕NA (BSO S), '|w_plot <PP P'
  'w_hist'  ⎕NA (BSO S), '|w_hist <PP F8 F8 P'
  'loadimg' ⎕NA (BSO S), '|loadimg >PP <C[] I'
  'saveimg' ⎕NA (BSO S), '|saveimg <PP <C[]'
  Z ← 0 0 ρ θ
∇

    Display ← {α ← 'Co-dfns' ⋄ W ← w_new ⊂α ⋄ 777 :: w_del W
                     w_del W ⊣ W αα{w_close α : ⍎'⎕SIGNAL 777' ⋄ α αα ω}⍣ωω ⊢ ω}
LoadImage ← {α ← 1 ⋄ ⍉ loadimg θ ω α}
SaveImage ← {α ← 'image.png' ⋄ saveimg (⍉ω) α}
      Image ← {~ 2 3 ∨.= ≢ρω : ⎕SIGNAL 4 ⋄ (3 ≠ 2 ⊃ 3 ↑ ρω) ∧ 3 = ≢ρω : ⎕SIGNAL 5 ⋄ ω ⊣ w_img (⍉ω) α}
        Plot ← {~ 2 ≠ ≢ρω : ⎕SIGNAL 4 ⋄ ~ 2 3 ∨.= 1 ⊃ ρω : ⎕SIGNAL 5 ⋄ ω ⊣ w_plot ω α}
 Histogram ← {ω ⊣ w_hist ω, α}
```

:EndNamespace