CPA Survival guide

Herman Roebbers

Nov-1-2009

TASS
software professionals

Dedicated to make it work.

In the beginning there was CSP …

- Communicating Sequential Processes
  - Process Algebra by C.A.R. (“Tony”) Hoare
    - ACM paper, 1978
    - Book, 1985 (Communicating Sequential Processes) **http://www.usingcsp.com/ - Prentice-Hall.**
  - Follow-up work by A.W. (“Bill”) Roscoe
    - Book, 1995 (The Theory and Practice of Concurrency) **http://web.comlab.ox.ac.uk/oucl/publications/books/concurrency/ - Prentice-Hall.**

TASS
software professionals

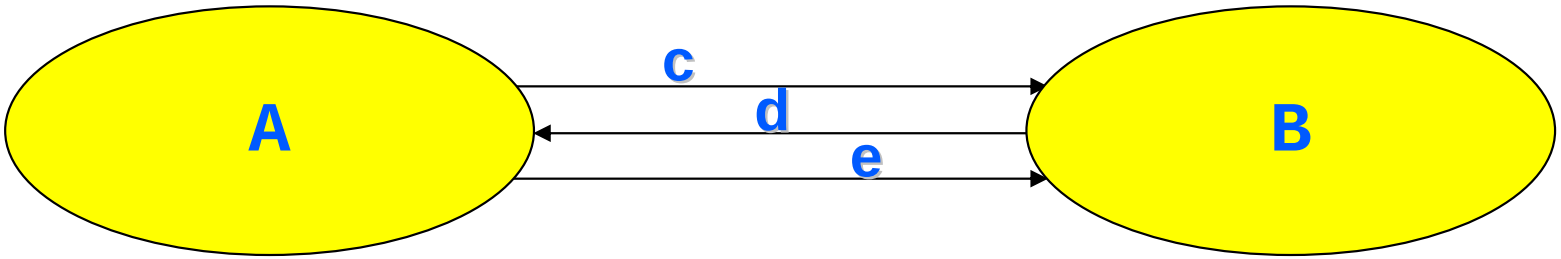
Communicating Sequential Processes

- Formal language (process algebra) describing parallel systems
- Related to Milner's Calculus of Communicating Systems (ca. 1980)
- Processes are entities that react on events
- Enables *specification* of behaviour patterns for processes (with respect to *events*) and their *refinement* into executable implementations

TASS
software professionals

Communicating Sequential Processes

- Parallel operator: `|SyncSet|`
  - `A|{c,d,e}|B` means `A` in parallel with `B`, synchronising (i.e. communicating) on channels `c`, `d` and `e`.



- Interleaved parallel operator: `|||`
  - `A|||B` means `A` in parallel with `B`, *free-wheeling* with no common synchronization.

TASS
software professionals

Communicating Sequential Processes

- Communication
  - takes place over channels
    - **`c?x`** means input to variable **`x`** from channel **`c`**
    - **`d!y`** means output the value of **`y`** over channel **`d`**
  - is unbuffered
  - is synchronous (rendezvous mechanism : first process waits until second is ready)
- You can construct your own buffering if need be – FIFO, overwriting, overflowing …

TASS
software professionals

Communicating Sequential Processes

- Non-determinism
  - external choice (**ALT**, **[]**): a process waits *passively* for one from a set of events (communications, timeouts, …) to become ready. If more than one is ready, it makes an *arbitrary* choice:

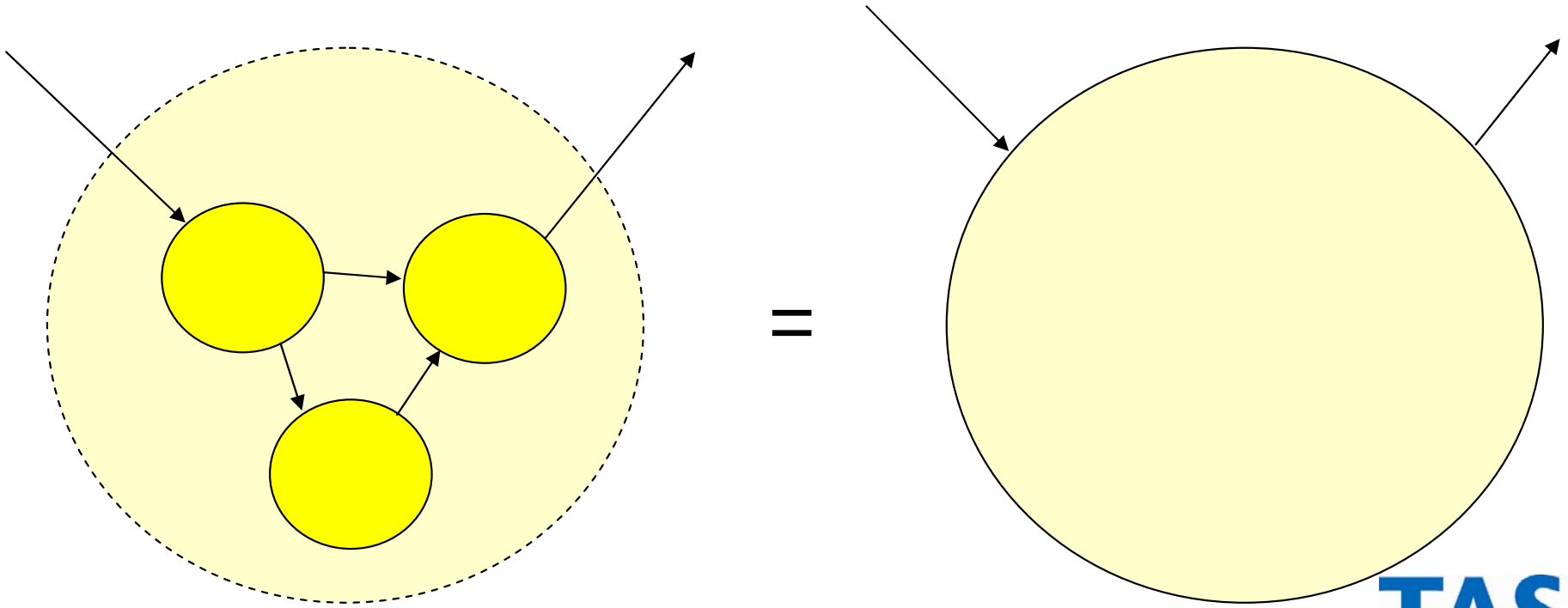
```
c?x -> P(x) [] d?x -> Q(x) [] e?x -> R(x)
```

In the above, the process waits for any of the three communications to be offered, chooses one that is offered and becomes the process following the corresponding arrow. For example, if **d?x** becomes available and is chosen, the message is collected in **x** and then **Q(x)** is executed.

TASS
software professionals

Communicating Sequential Processes

- A sub-network of processes is itself a process.



Communicating Sequential Processes

- Example Vending Machine :
  - Accepts coin, delivers tea, then returns to previous state :

```
VM = coin -> tea -> VM
```

Communicating Sequential Processes

- Traces:
  - Sequences of events in which the process has engaged
  - Possible traces of **VM**:

```
< >
< coin>
< coin, tea >
< coin, tea, coin >
< coin, tea, coin, tea >
< coin, tea, coin, tea, coin >
< coin, tea, coin, tea, coin, tea >
```

  - **etc., etc.**

TASS
software professionals

Communicating Sequential Processes

- Other commonly used CSP terms:
  - Failure (deadlock)
  - Divergence (livelock)
  - Refinement
    - from specification to implementation …

TASS
software professionals

Communicating Sequential Processes

CSP is a formal process algebra =>

Programs can be checked for:

- Equivalence
- Certain properties (deadlock, livelock)

This can be done for example by the program FDR2 from Formal Systems (**`http://www.fsel.com`**)

TASS
software professionals

Communicating Sequential Processes

- FDR2 does not deal with the mathematical notation of CSP directly (too many special symbols!)
  - FDR2 needs representation of CSP programs.
    - Machine readable CSP (CSP_M)

TASS
software professionals

Variations on / extensions of CSP (1)
π-calculus (Robin Milner)

- another *process algebra* (similar in some respects to CSP) with the addition of:
  - Mobile channels: Channels can be dynamically created and sent to other processes over existing channels. Enables the creation of network topologies dynamically (e.g. in response to run-time demands)
  - Mobile processes: Processes can be dynamically created and sent over channels – again giving rise to dynamic networks … also *mobile agent* technologies.

TASS
software professionals

Variations on / extensions of CSP (2)
CSP with the addition of time:

Timed CSP (Steve Schneider)

- real-time issues …
- Book (Concurrent and real-time systems. The CSP Approach), 1999, John Wiley & Sons.
  `http://www.cs.rhbnc.ac.uk/books/concurrency/`

TASS
software professionals

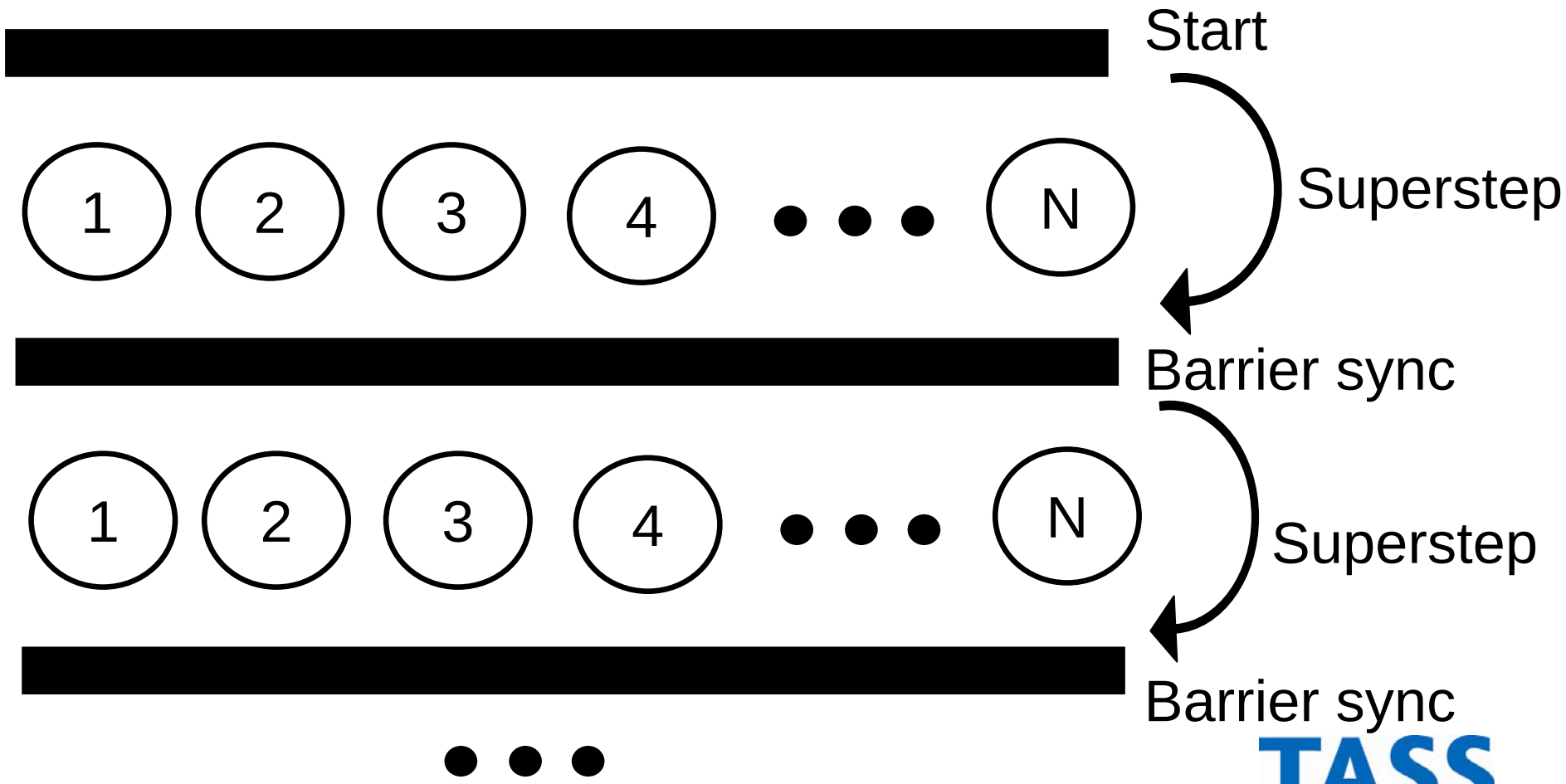
Bulk-Synchronous Parallelism

Leslie G. Valiant (ca. 1998), W.G. (“Bill”) McColl:

- The von Neumann model of sequential computation is successful because:
  - Efficient bridge between software and hardware: high-level languages can be efficiently compiled on to this model
  - Yet it can be efficiently implemented in hardware.
- Analogous bridge between software and hardware is required for parallel computation to become as widely used => BSP

TASS
software professionals

Bulk-Synchronous Parallel



Bulk-Synchronous Parallel

DEC / Compaq Alpha CPU has special pins to implement barrier sync in hardware!

TASS
software professionals

occam

Lean parallel programming language based on CSP, designed together with transputer

- Keywords:
  - SEQ PAR ALT ? ! WHILE IF FOR AFTER IS PROC SIZE
- Indentation has syntactic meaning: WYSIWYG
- Replication (e.g. PAR i = 0 FOR 4)
- Lots of semantic checks (compile time and run-time)
  - Alias check
  - Usage check

TASS
software professionals

Transputer (Inmos, ca. 1984)

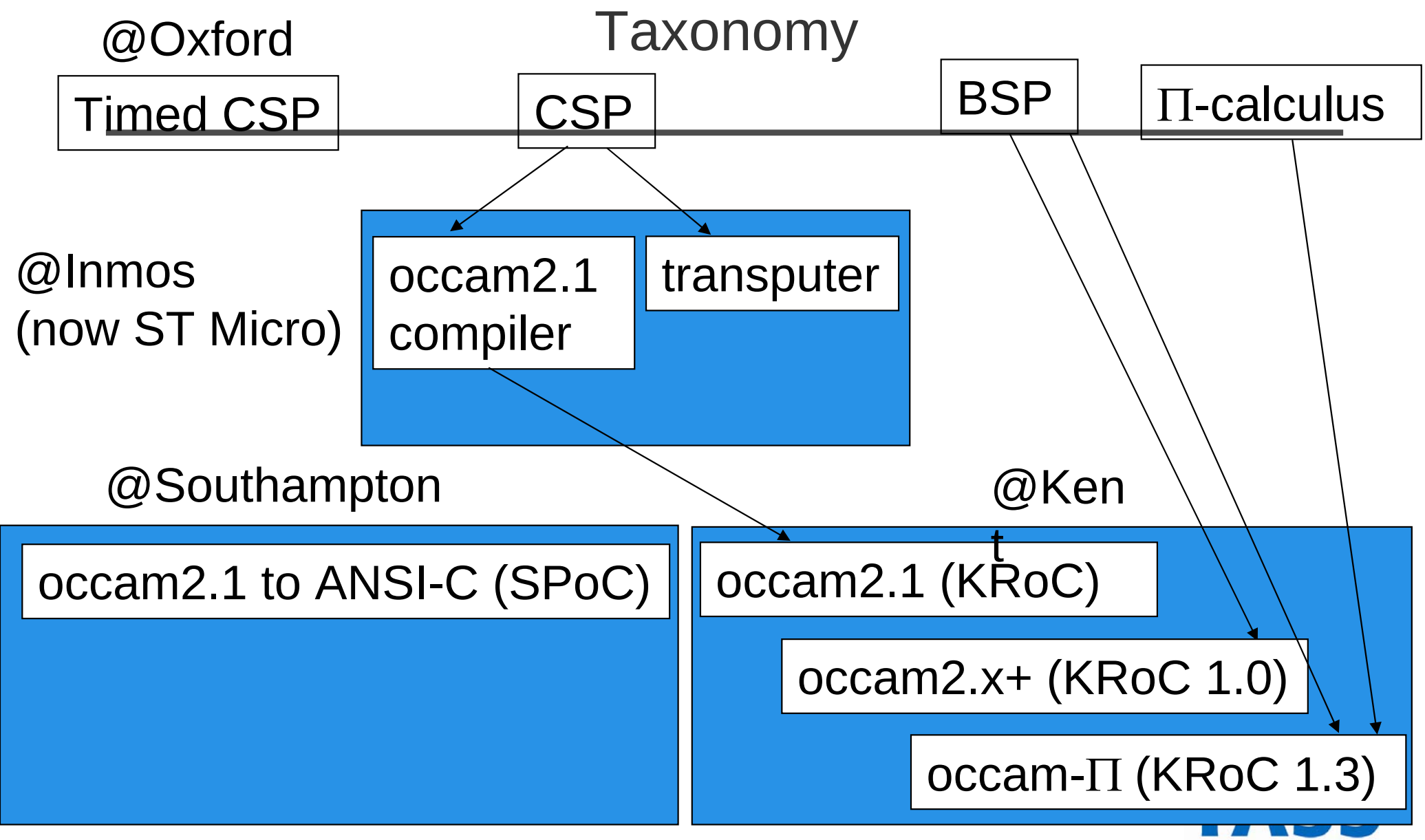
- Microprocessor intended to be as universal as transistor (**trans**istor com**puter**), to be used in networks
- Bidirectional serial links at 5 – 100 Mbit/sec with hardware handshake protocol and DMA, automatic scheduling
- Micro-coded hardware round-robin scheduler with 2 priorities
- Instructions for communication and scheduling
- Instructions much like current java byte code

TASS
software professionals

Transputer (ST Micro, ca. 2000)

- The transputer is NOT dead …
- It is transformed into the ST20 processor inside many ST Microelectronics Set Top Box / DVD / Digital Video Broadcasting / GPS chips, which are selling by the millions.
- The ideas pioneered by the transputer (that concurrency, communication and computation are '*first-class*' operations – equally in need of hardware support) are fundamental to the next generation multi-processors.

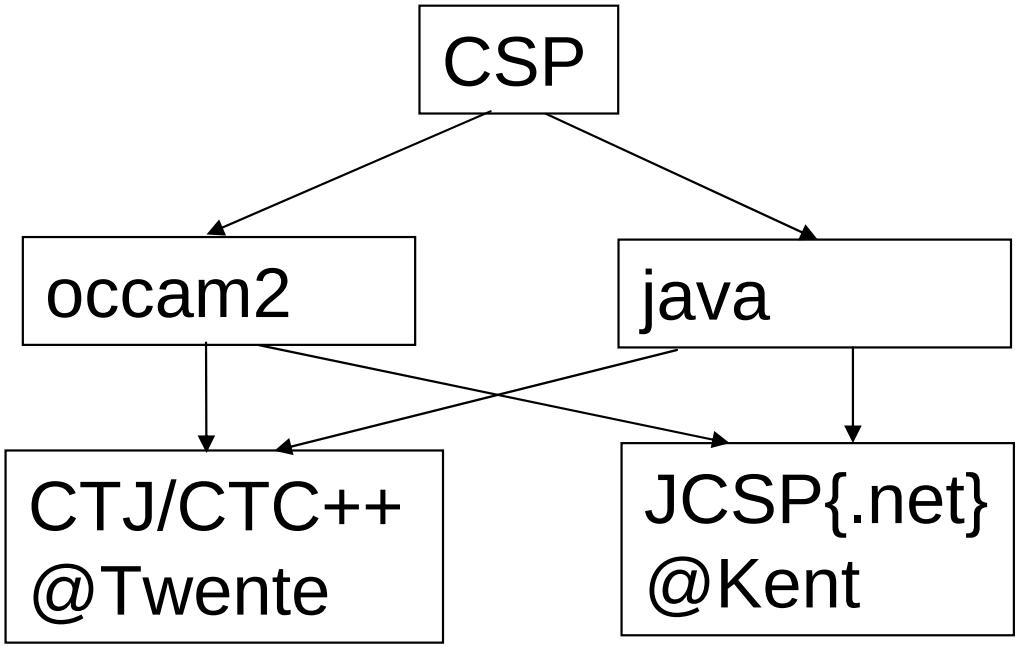
TASS
software professionals



SPoC = Southampton Portable occam Compiler

KRoC = Kent Retargeted occam Compiler (x86,SPARC,MIPS, ...)

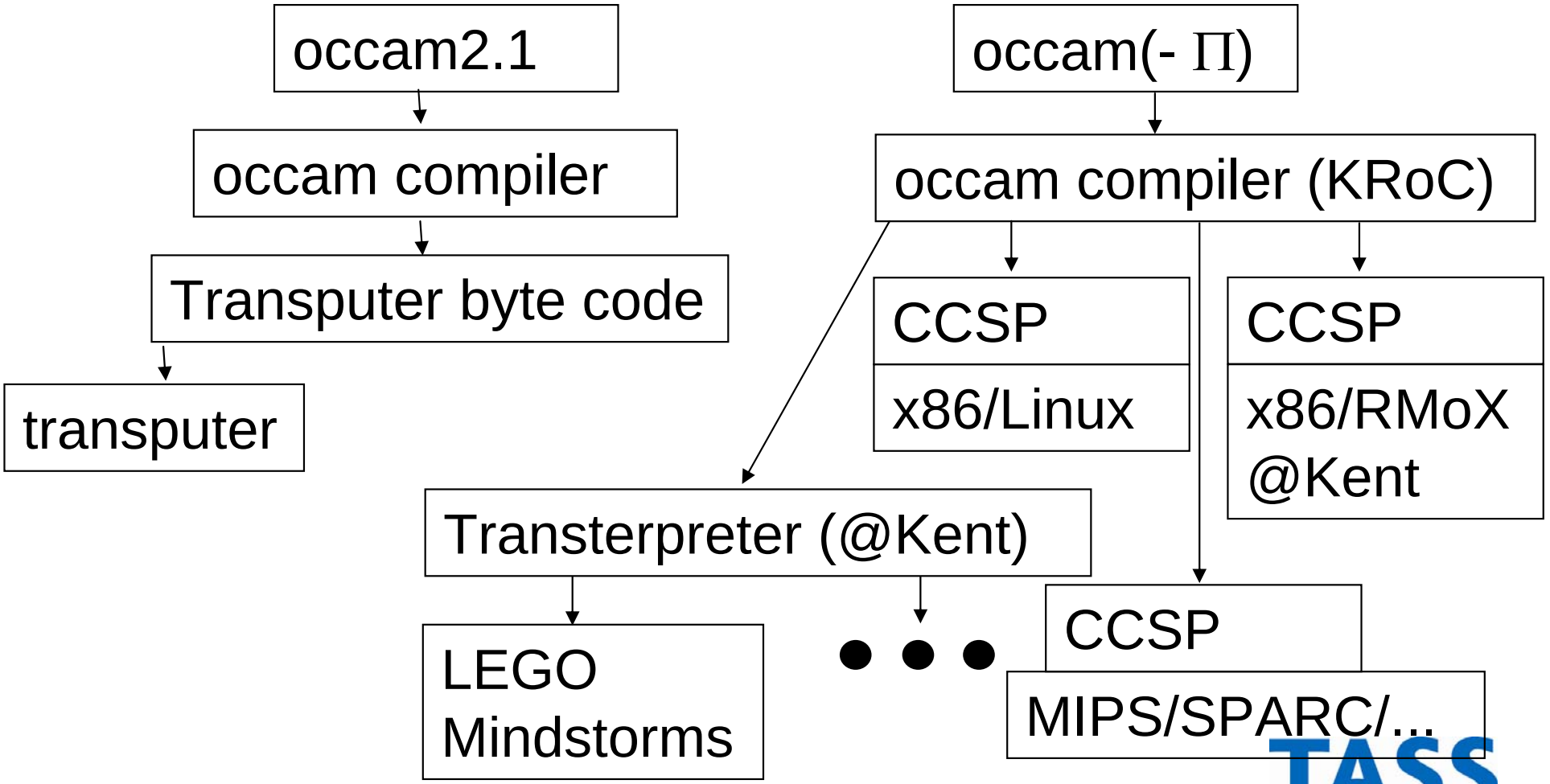
Taxonomy(2): java Class Libraries Implementing CSP Semantics



CTJ = Communicating Threads for Java/C++

JCSP = Java Communicating Sequential Processes

Taxonomy(3)
occam execution engines

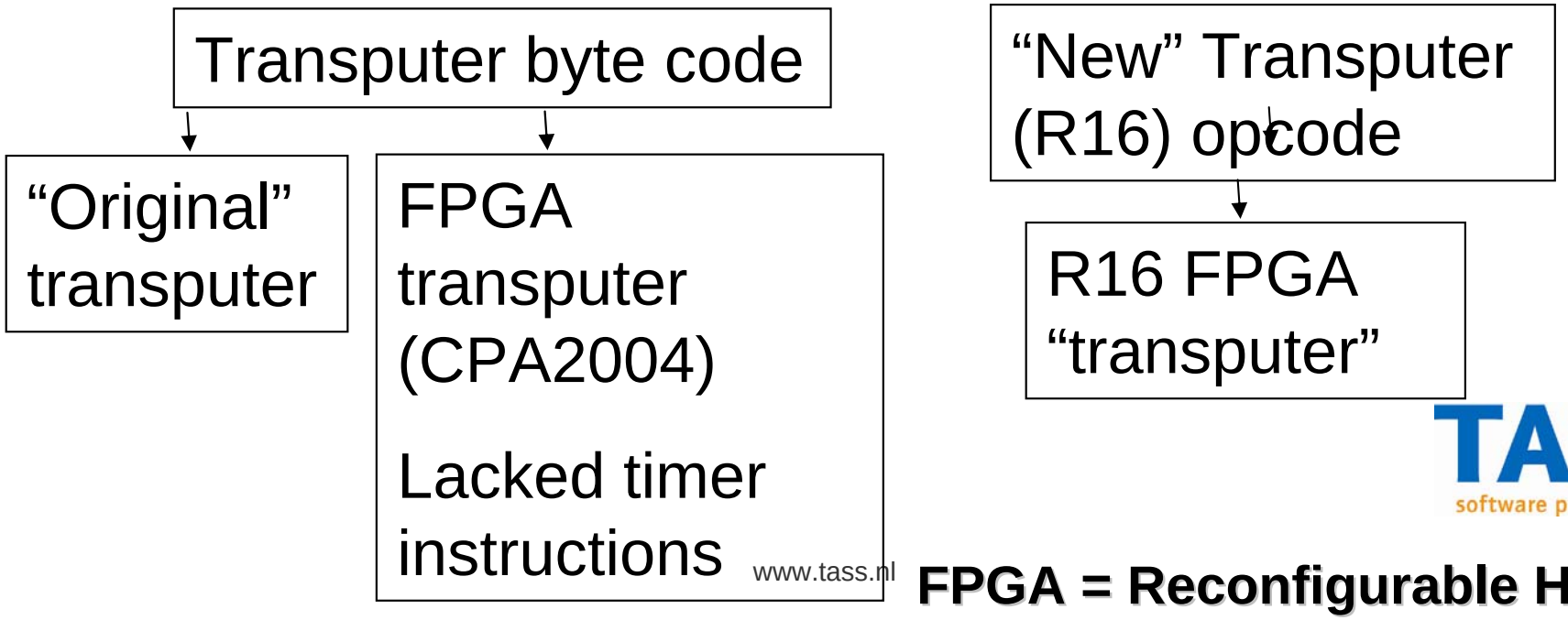


CCSP = Portable CSP based runtime supporting C and occam

RMoX = Raw Metal occam eXperiment : running on PC without O/S

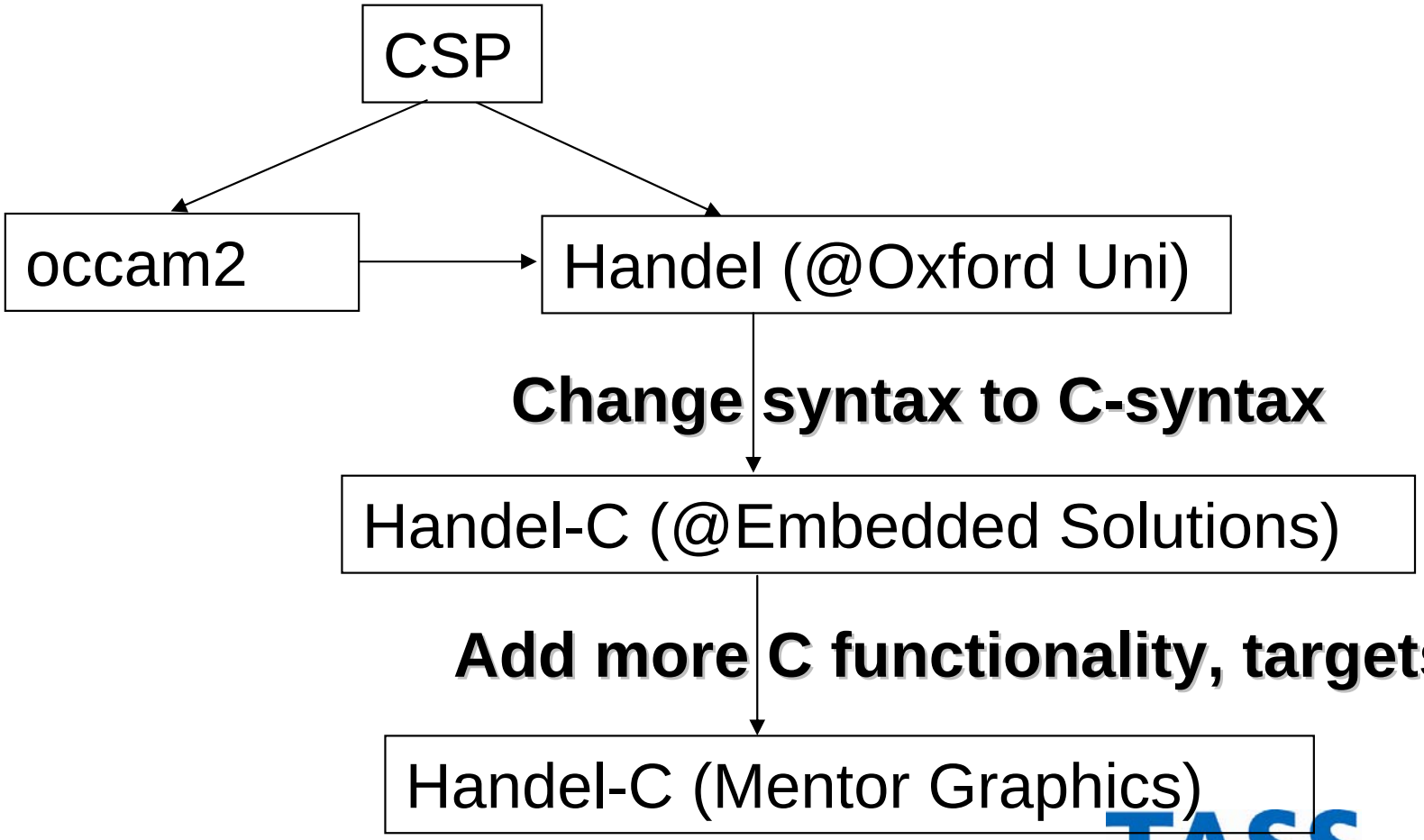
Taxonomy(4)
Transputer incarnations

Transputer = high-performance processor for efficient execution of multiprocessing code and high-speed serial links integrated through communication instructions



TASS
software professionals

Taxonomy(5)
CSP for Hardware Design



TASS
software professionals

CPA 2009 is about much more than occam and transputers.

TASS
software professionals

CPA2009 is open!

Questions???

TASS
software professionals

Dedicated to make it work.