Collabora Productivity

Free your business

The driving force behind putting #LibreOffice in the #Cloud.

Calc: The challenges of scalable arithmetic

How threading can be challenging

Michael Meeks

General Manager at Collabora Productivity

michael.meeks@collabora.com

Skype - mmeeks,

G+ - mejmeeks@gmail.com

"Stand at the crossroads and look; ask for the ancient paths, ask where the good way is, and walk in it, and you will find rest for your souls..." - Jeremiah 6:16

Calc threading - Overview

- LibreOffice 6.0 Calc
- Existing structure & parallelism
- Why thread ?
- The initial solution & problems
  - mis-factored code
  - dependency issues
- The group calculation piece
- Profiling & optimizing
- Future work & expansion ...

Disclaimer & Thanks:

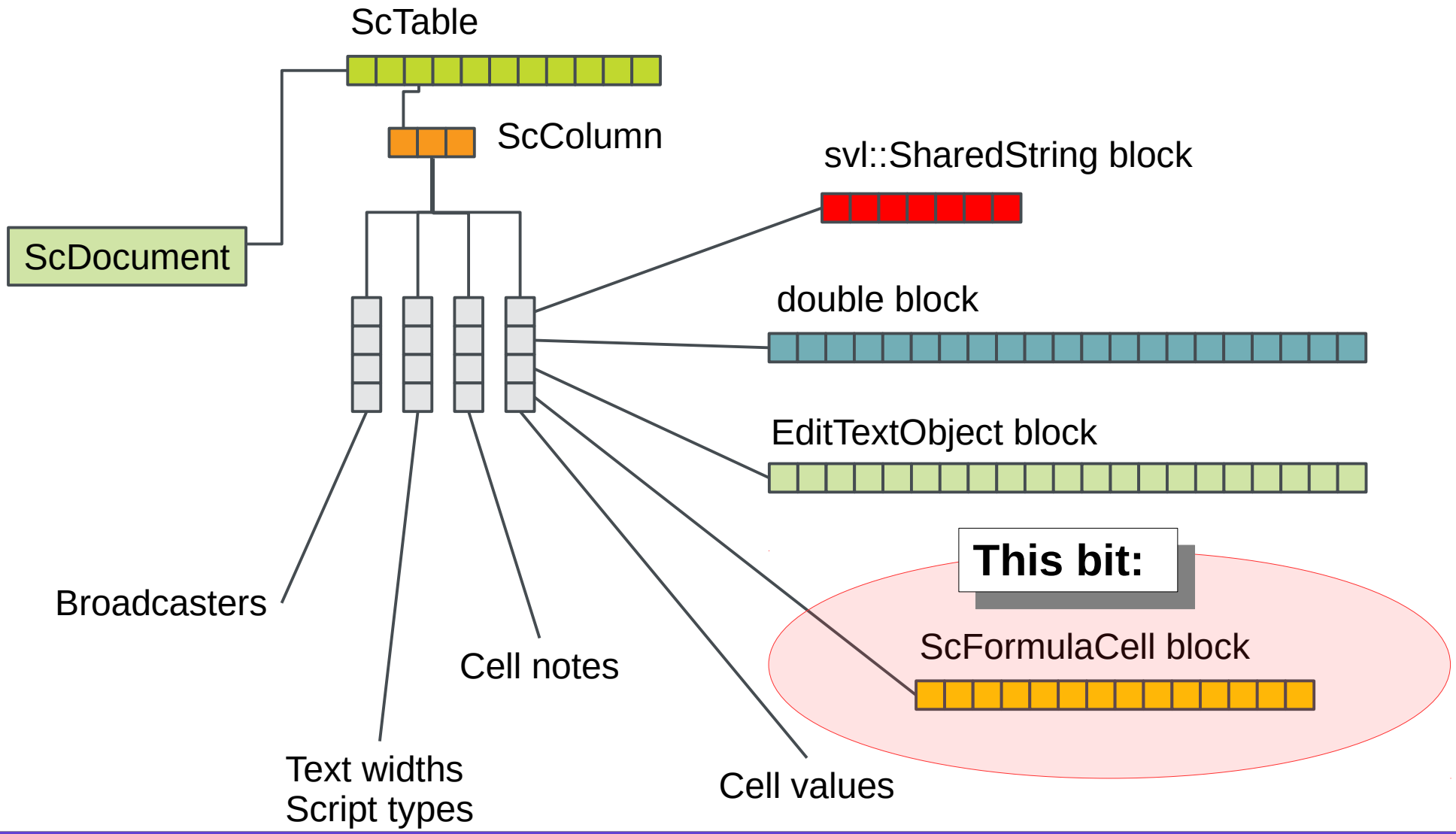
Almost all of this work was done by Tor Lillqvist & Dennis Francis – who can't be here today.

Some great code reading & improvement.

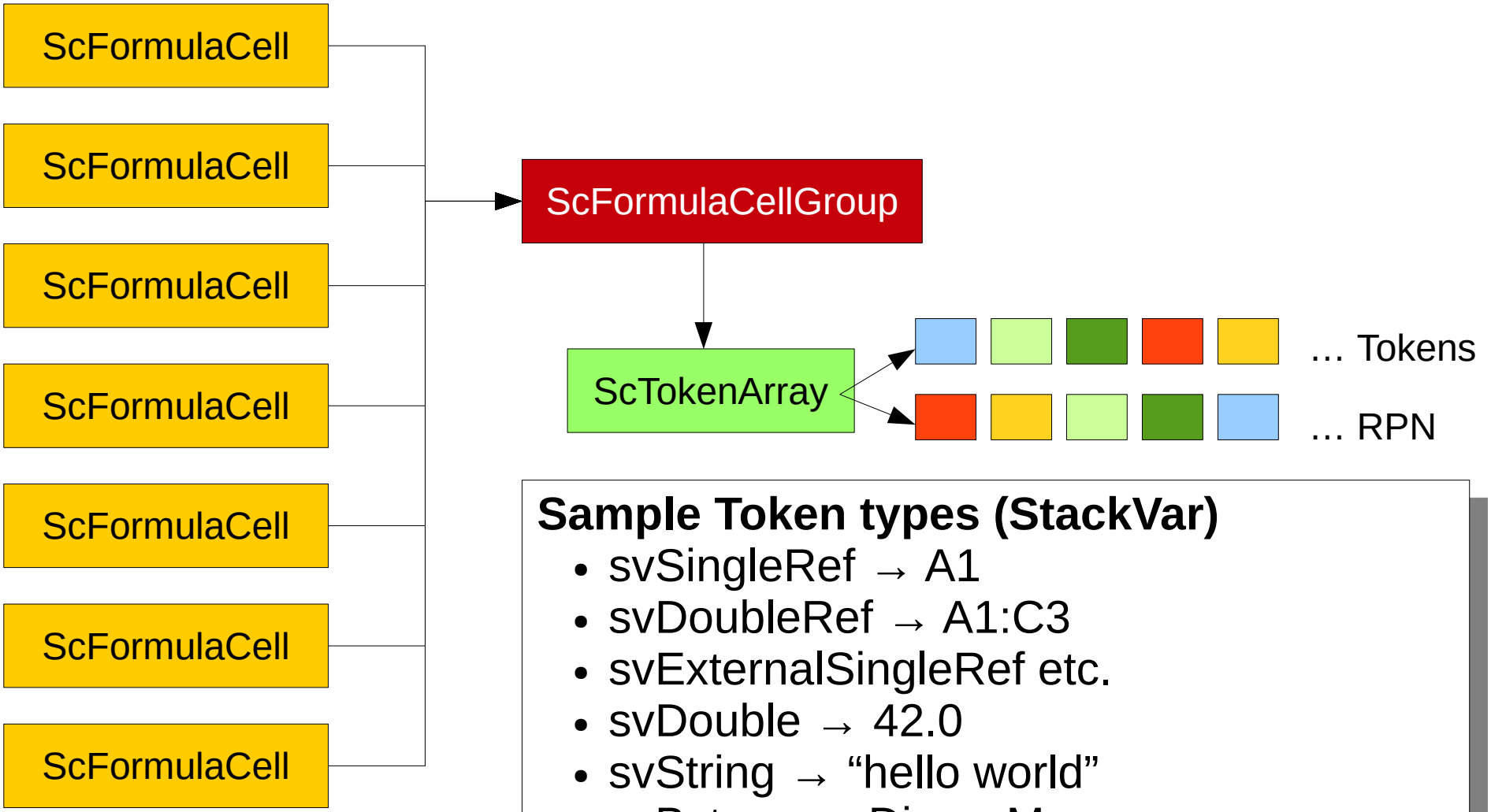
LibreOffice 6.0 Calc ...

- A 30+ year old code-base
- Primary Data structures hugely improved recently
  - Still some scope for improvement: FormulaGroup vs. FormulaCell, per-cell dependency records etc.
- Calculation Engine in need of love
  - Some insights into how it works
  - Some problems wrt. threading.

Core structures since 4.3 (mdds::multi_type_vector)



FormulaCellGroups

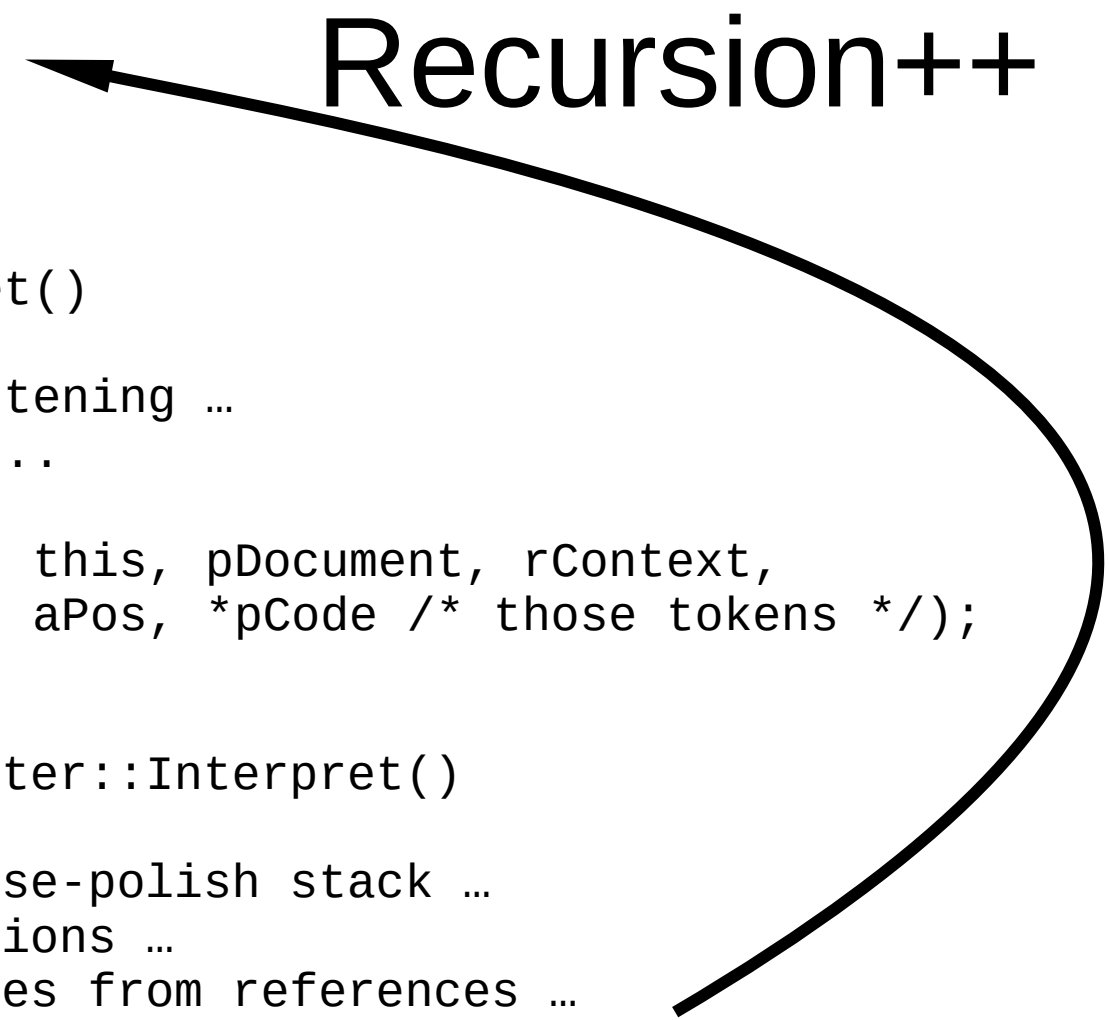


Sample Token types (StackVar)

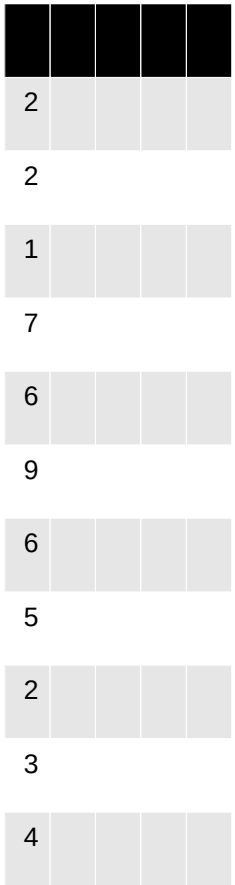
- svSingleRef → A1
- svDoubleRef → A1:C3
- svExternalSingleRef etc.
- svDouble → 42.0
- svString → “hello world”
- svByte → ocDiv, ocMacro ...

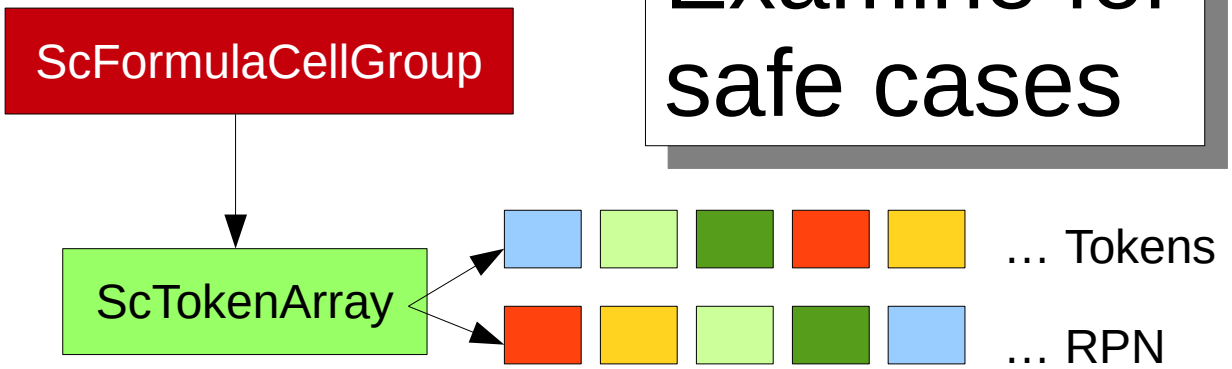
Normal Formula interpreting

```
double ScFormulaCell::GetValue()
{
    MaybeInterpret();
    return GetRawValue();
}
     void ScFormulaCell::Interpret()
     {
         … amazing recursion flattening …
         InterpretTail() // ie. ...
         {
             … new ScInterpreter( this, pDocument, rContext,
                                  aPos, *pCode /* those tokens */);
                ->Interpret()

              StackVar ScInterpreter::Interpret()
              {
                  … execute reverse-polish stack …
                  … execute functions …
                  … get cell values from references …
```



InterpretFormulaGroup





getValues Collected to Matrix

Interpret: OpenCL Software

Even non-threaded software case: faster

Shares function input collection work.

Aggregated / linearized doubles / strings in the matrix

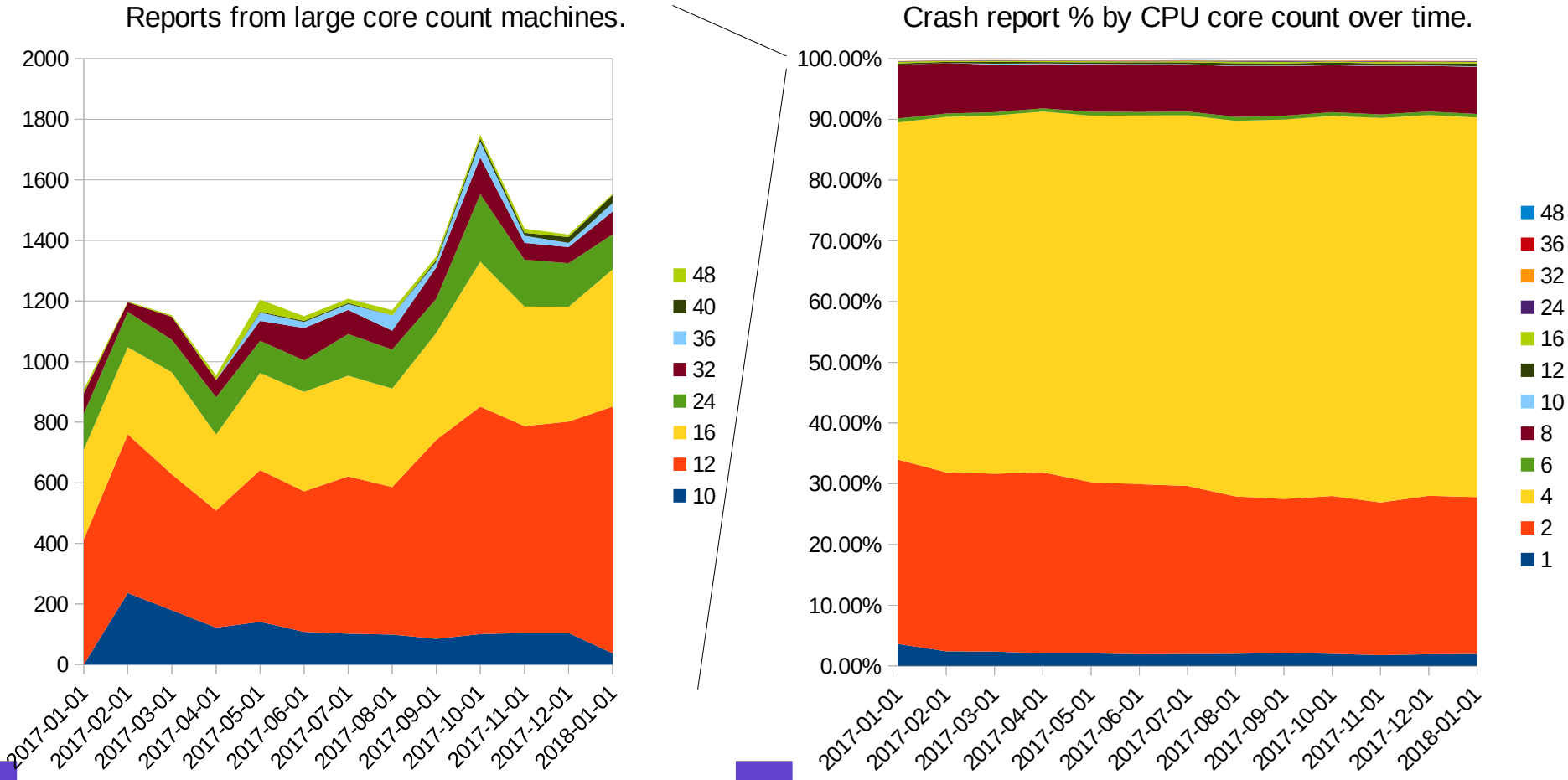
Why Thread ?

CPUs get wider not faster

- Sometimes CPUs get slower ...
- Process clocks stymied at 3-4 GHz
  - IPC improvements ~stalled
- Real IPC wins:
  - Laptops → minimum 4 threads
    - Mid-range → 8 threads.
  - PC / Workstation
    - 8 → 16 threads: the new normal.
  - Affordable too ...
- Many thanks to AMD for sponsoring this work.

2017 Crash reporting stats

- Frustratingly ‘cores’ not threads.



Initial Solution …

Thread InterpretFormulaGroup

- Attempt re-use of existing formula core
  - Try to avoid special / sub-setting code-paths for existing formula-group conversion: a more generic solution.
- Concept:
  - Pre-calculate dependent cells to control recursion outside of threads.
  - Protect invariants with assertions
  - Black-list problematic functions ...
  - Parallelise using existing interpreter.

Parallelize existing interpreter

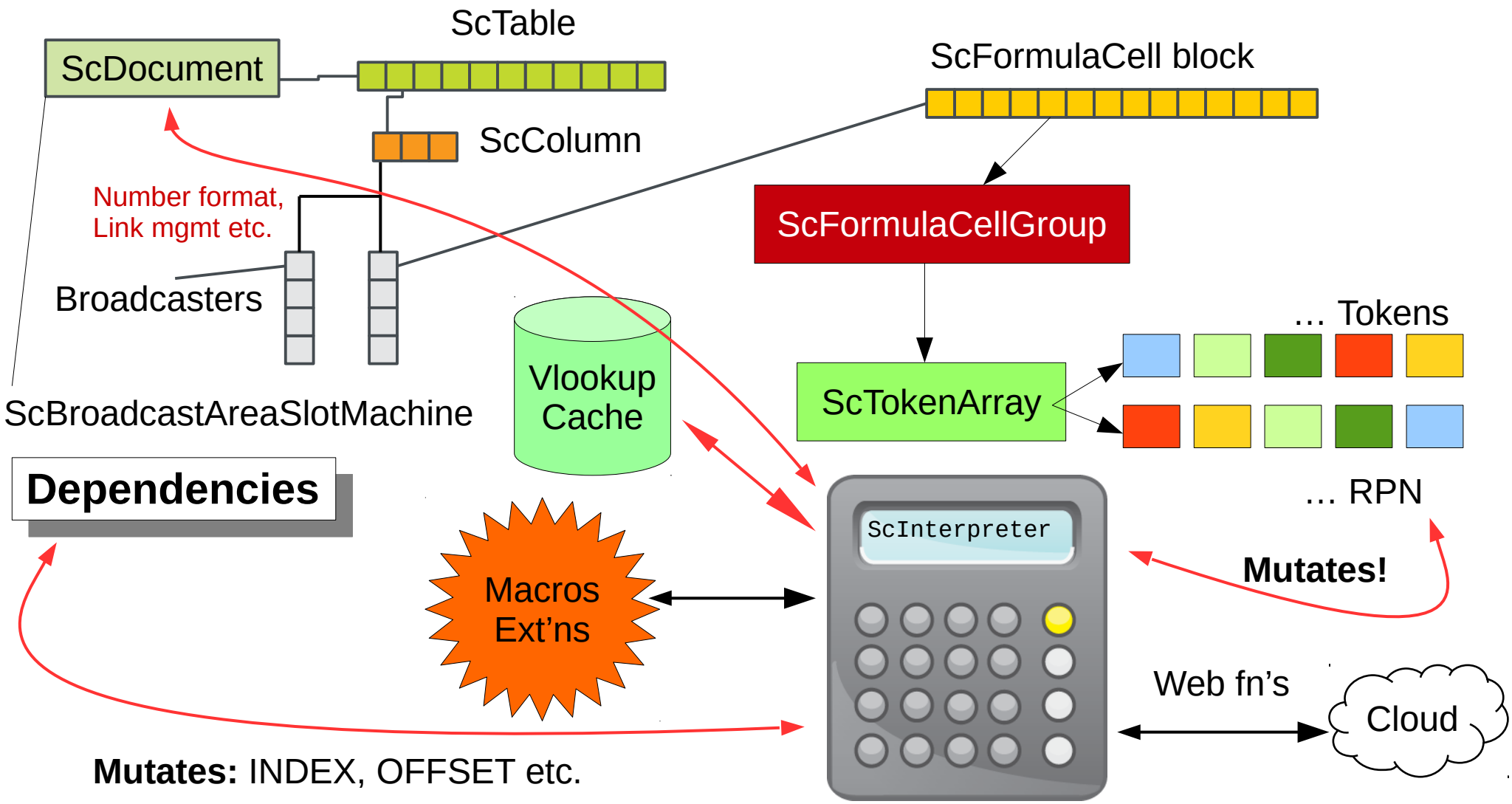
```
double ScFormulaCell::GetValue()
{
    MaybeInterpret();
    return GetRawValue();
}

void ScFormulaCell::Interpret()
{
    … amazing recursion flattening …
    InterpretTail() // ie. ...
    {
        … new ScInterpreter( this, pDocument, rContext,
                             aPos, *pCode /* those tokens */);
           ->Interpret()
               StackVar ScInterpreter::Interpret()
               {
                   … execute reverse-polish stack …
                   … execute functions …
                   … get cell values from references …
```

Pre-fetch all dependent values – and lock-that down:

```
void ScFormulaCell::MaybeInterpret() ...
assert(!pDocument->mbThreadedGroupCalcInProgress);
```

Pre-calculated → No recursion

ScInterpreter: calcs formulae



ScInterpreter: some fixes

- Basic iteration - broken:
  - `class FormulaTokenArray`
    - `sal_uInt16 nIndex; // Current step index`
    - `FormulaToken* FirstRPN() { nIndex = 0; return NextRPN(); }`
  - Now has an external iterator
    - a man-week+ to un-wind this, and debug the last pieces that relied on this.
- Added mutation guards:
  - `ScMutationGuard aGuard(this, ScMutationGuardFlags::CORE);`
    - In all likely-looking places: where core state is changed.

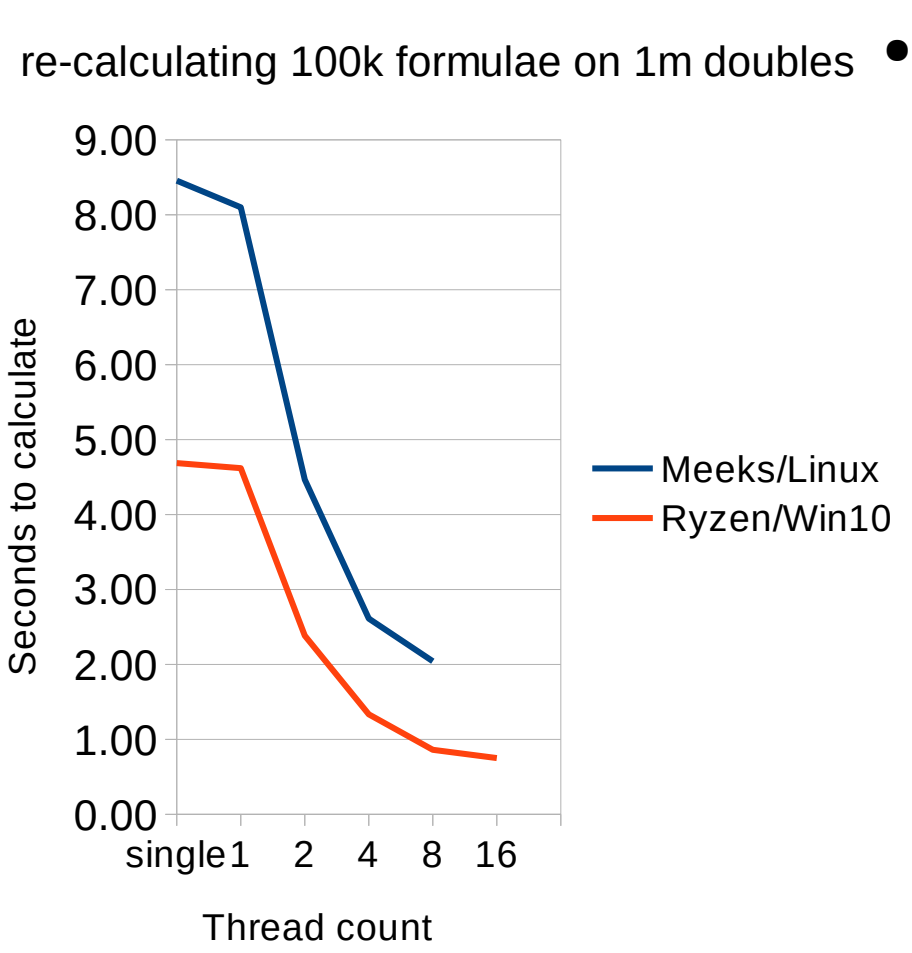
Disabling nasties:

- Dependency graph manipulation
  - During calculation:
    - Indirect, Offset, Match, Cell, ocTableOp
- Other stuff
  - Macros – disabled for now.
    - Could detect ‘pure’ ie. non-mutating functions
    - Also parallelize the basic/ interpreter (?)
  - Info → grab-bag of bits.
  - ocExternal → UNO extensions:
    - currently in: but can do ~un-controlled mutation (?)

More nasties ...

- Several global variables
  - No-where obvious to hang them
  - Now some `thread_local` variables
    - *Calculation stack*
    - *Current-document being calculated*
    - *Matrix positions – nC,nR*
  - Somewhat horrific: fix obsolete Mac toolchain.
- ScInterpreterContext
  - Added – passed through all functions.
    - Impacts eg. ‘GetValue’ though ...

How did that look: initially ...



- Faster
  - Getting some nice speedups – ignoring the hyper-threaded-ness:
  - 8.5s → 2.5 with 4 threads → 3.4x
  - 4.7 → 0.86 - ~5.5x with 8 threads

Up to this point:

- Plain Old calculation – single threaded (POC)
- Group calculation
  - A) Single Threaded Software Group calc (STSG)
  - B) OpenCL: GPU parallelism after conversion
  - C) New threaded calculation (NTC)
- **Then: C) slower than A)** in some cases …
  - Collecting data from sheets, branching, type handling, etc. again and again for each formulacell …
    - Expensive – threading doesn't help.
  - A) collects once – and has some SSE2 goodness …
- So → add a 'threaded A)' - simple & better …
- Weighting decision: POC vs. … based on complexity.

Improving performance ...

- Why don’t we get a 8x for 8 threads ?
  - Terrible profiling tools on Windows.
  - Linux – used ‘perf’ looking for threading issues:
    - `sudo perf record --call-graph dwarf \ --switch-events -c 1 # etc.`
  - Looking for false-sharing
    - And other horrors.

Horror: rampant heap thrash

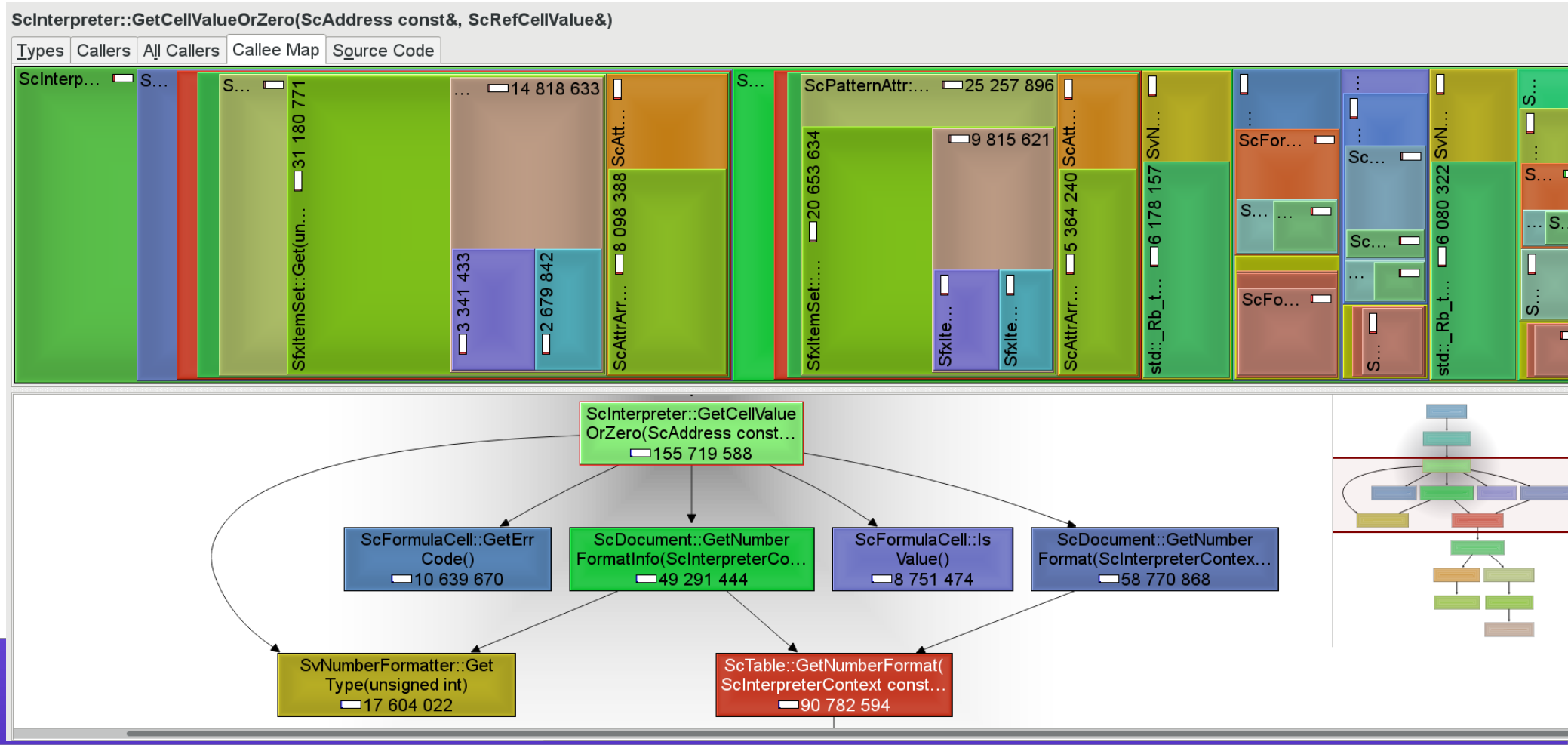
- RPN calculation – stack based:
  - Tons of stack operations: pushing values etc.
  - Do memory allocation & frees.
    - Using the ancient / internal allocator – never intended for heavy parallel use.

    → drop the custom allocator → hugely faster

    → Re-use tokens where possible too.
- std::stack → deque → lists ...
  - Horrible: std::vector instead → far better.
- Re-using ScInterpreterContext ...

Other issues ...

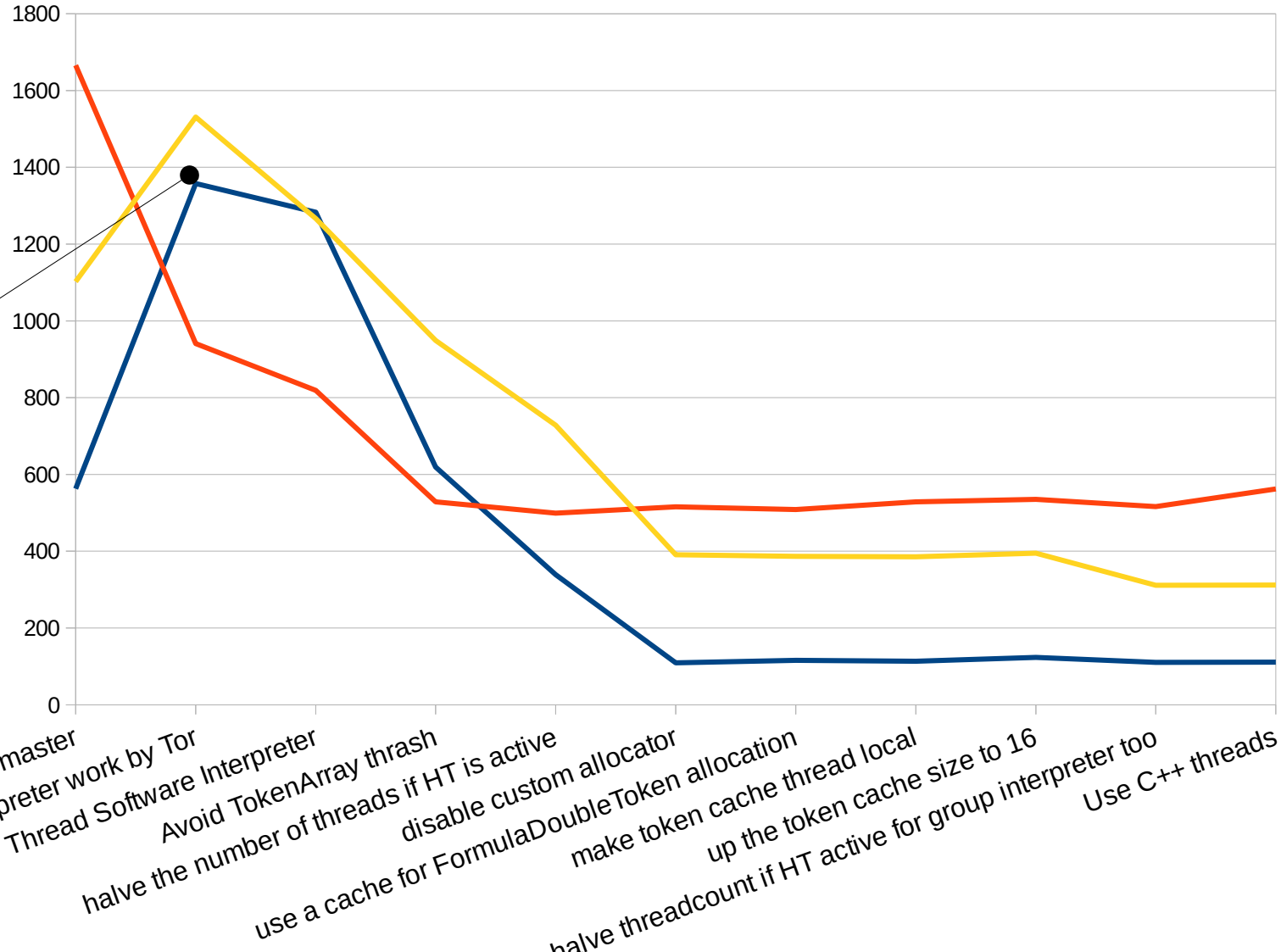
- Where ‘GetDouble’ meets SfxItemSet ...
- fixed SvNumberFormatter thread safety.



Threading & optimizing story:

Benchmarking some of our sample sheets ...

Note this perf. Regression from threading for some workloads came from avoiding the SoftwareGroupInterpreter

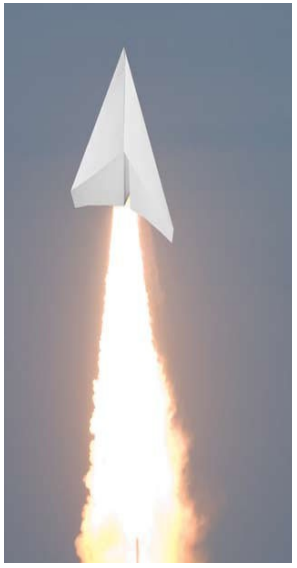


Future work

- Stop the Crash-testing from asserting ...
  - Implicit intersection: killing us (again)
    - Move RPN to have precise ranges
- Extend threaded unit tests further ...
- Move more global variables to ScInterpreterContext
- Make FormulaCell a 1x item group
  - Make POC calcalation a forced-single-threaded calc
    - Always thread SoftwareGroup Intepreter
- De-bong the format-typeuse
  - =J20 – should not change format type if J20 changes format.
    - A sheet-creation-time optimization ...
    - Intersects with ‘units’ work too.

Conclusions

- Calculation can be threaded
- Significant speedups are possible
- Profiling & optimizing works
  - *“it is slow” == “not enough invested yet”*
    - All problems are just economics
- Many thanks to AMD for their support.



Oh, that my words were recorded, that they were written on a scroll, that they were inscribed with an iron tool on lead, or engraved in rock for ever! I know that my Redeemer lives, and that in the end he will stand upon the earth. And though this body has been destroyed yet in my flesh I will see God, I myself will see him, with my own eyes - I and not another. How my heart yearns within me. - Job 19: 23-27