

# Heterogeneous applications

Using Intel® Threading Building Blocks and Intel® Cilk Plus  
Based on Intel TBB fractal package example

Vladimir Polin

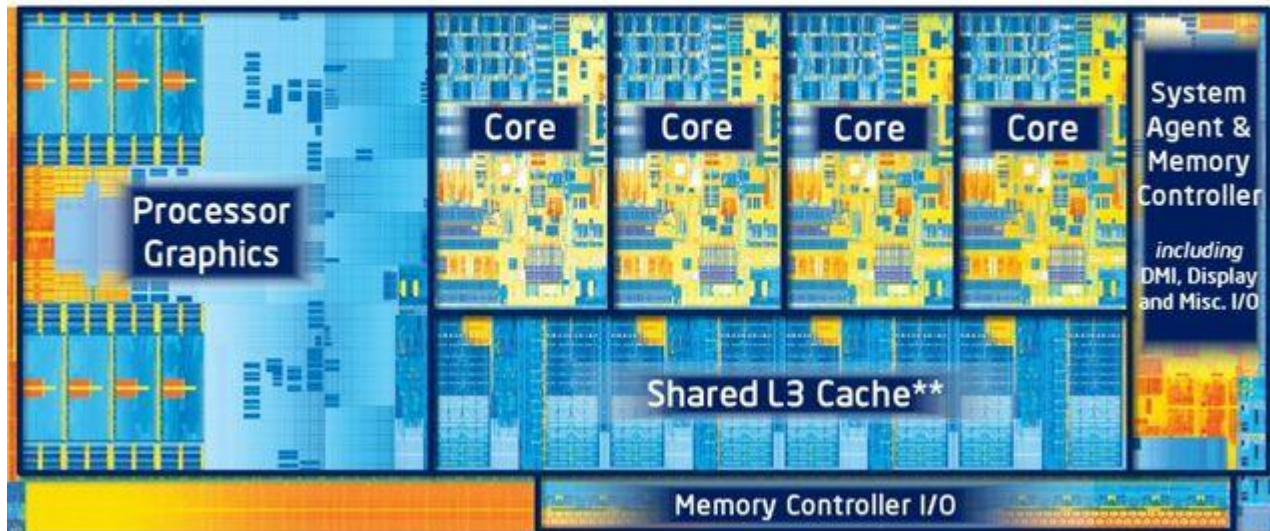
Threading Runtimes Engineering Manager

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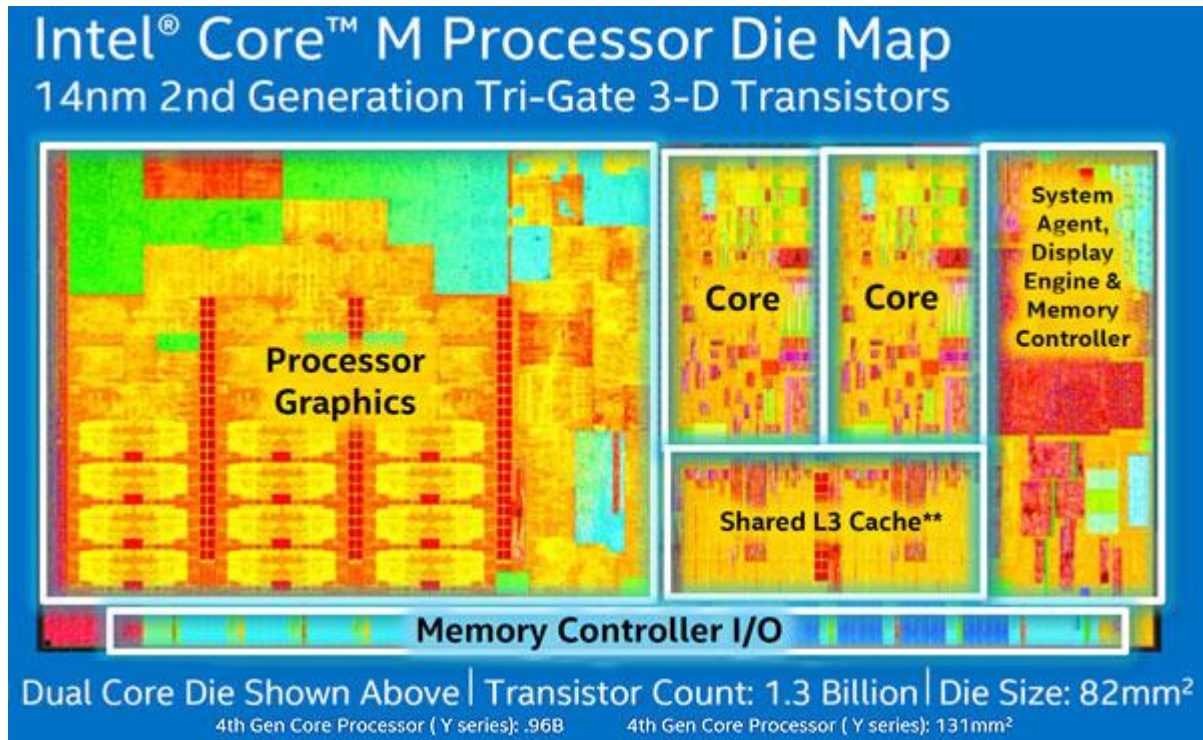
# Past

## 3rd Generation Intel® Core™ Processor: 22nm Process



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# Present



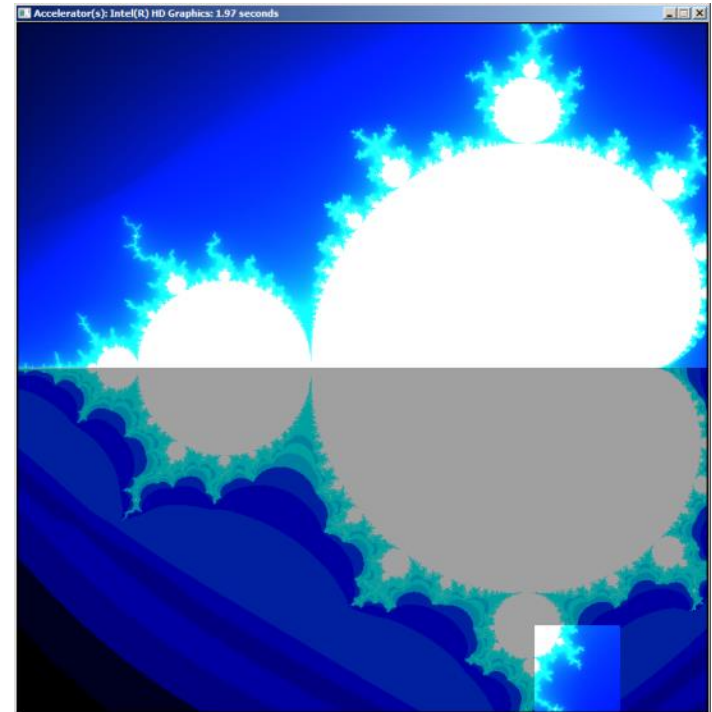
**How we can use and utilize this processor graphics?**

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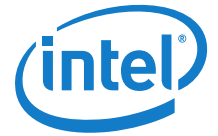
# Mandelbrot set



- Simple Mandelbrot set
- Open Source
- Part of the Intel TBB package
- Important:
  - Demo purposes only
  - Vivid picture



# Example of parallel\_for work



?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
<b>1</b>	<b>3</b>	?	?	?	?	?	?
<b>2</b>	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?

? – means stealing.  
Nobody knows where calculation will be started and how stealing will work



# Initial Code

## Calling calculation of a set parts in parallel

```
tbb::parallel_for(tbb::blocked_range2d<int>(0, size_y, grain_size, 0, size_x, grain_size),
    [&](tbb::blocked_range2d<int> &r){
    if (v->next_frame())
        render_rect(r.cols().begin(), r.rows().begin(), r.cols().end(), r.rows().end());
    },
    tbb::auto_partitioner());
```

## Processing every set part

```
color_t fractal::calc_one_pixel(float x0, float y0)
{
    return calc_one_pixel(x0, y0, max_iterations, size_x, size_y, magn, cx, cy, 255);
}

void fractal::render_rect(int x0, int y0, int x1, int y1){
    // render the specified rectangle area
    drawing_area area(off_x+x0, off_y+y0, x1-x0, y1-y0, dm);
    for (int y=y0; y<y1; ++y){
        area.set_pos(0, y-y0);
        for (int x=x0; x<x1; ++x){
            area.put_pixel(calc_one_pixel(x, y));
        }
    }
}
```

# User-Managed Task Arenas

- an arena is a place for threads to share and steal tasks
- Name - task\_arena class
- represents an internal task scheduler object where a number of threads, limited by a maximal concurrency level, share and execute tasks.
- The concurrency level of a task\_arena is isolated and not affected by previous task\_scheduler\_init specifications.

# Example of parallel\_for work with 2 arenas



Outer Arena

?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
1	3	?	?	?	?	?	?
2	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?

Inner Arena

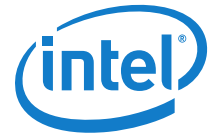
?	?	?	?	?	?	?
?	?	?	?	?	?	?
?	?	?	?	?	?	?
?	?	?	?	?	?	?
?	?	?	?	?	?	?
?	?	?	?	?	?	?

CPU work

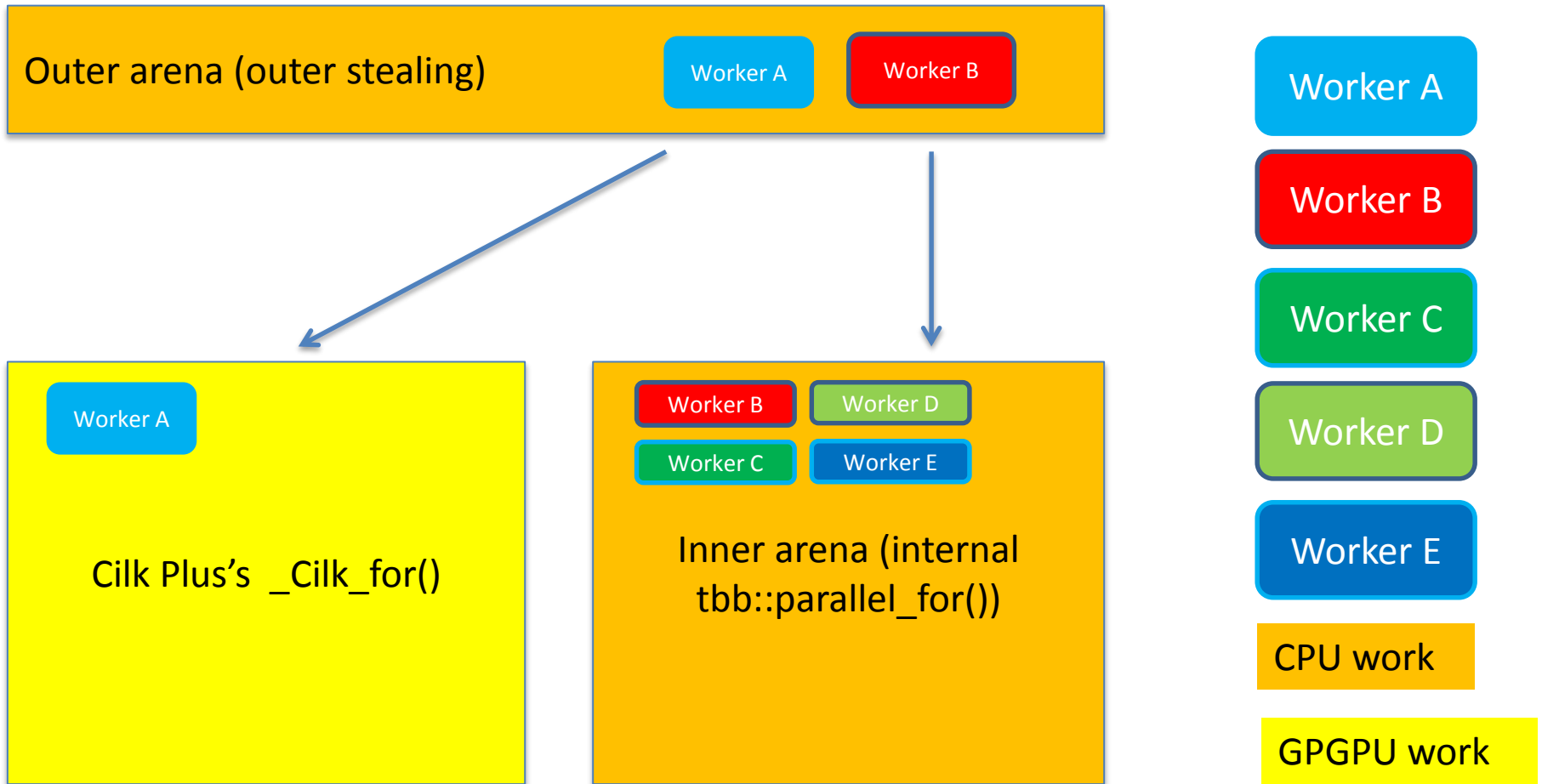
GPGPU work

? – means stealing.  
Nobody knows where  
calculation will be started  
and how stealing will work





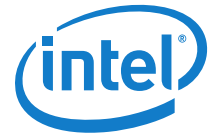
# Task arenas in action



## Outer arena (outer stealing)

Worker A

Worker B



```
tbb::task_arena outer_arena(2);
outer_arena.execute([&]·(){
····tbb::parallel_for(tbb::blocked_range2d<int>(0, size_y, grain_size, 0, size_x, grain_size),
····· [&]·(tbb::blocked_range2d<int>·&r){
····· if·(-v->next_frame()·)
····· render_rect(r.cols().begin(), r.rows().begin(), r.cols().end(), r.rows().end());
····· },
····· tbb::auto_partitioner());
});
```



Worker A

## Cilk Plus's `_Cilk_for()`

```
.....const int delta_x = x1 - x0; const int delta_y = y1 - y0; int delta_y2; int idx = 0; int status;
.....unsigned _int32 fractal_data_array[delta_x][delta_y];
#pragma offload target(gfx) pin(fractal_data_array: length((delta_x)*(delta_y)))
....._Cilk_for(int y = 0; y < delta_y; ++y) {
.....    _Cilk_for(int x = 0; x < delta_x; ++x) {
.....        fractal_data_array[x][y] =
.....            calc_one_pixel(tmp_off_x + x, tmp_off_y + y, tmp_max_iterations, tmp_size_x, tmp_size_y, tmp_magn, tmp_cx, tmp_cy, 160);
.....    }
.....}
.....drawing_area.area(off_x + x0, off_y + y0, x1 - x0, y1 - y0, dm);
.....for (int y = y0, y_temp = 0; y < y1; ++y, ++y_temp) {
.....    area.set_pos(0, y - y0);
.....    for (int x = x0, x_temp = 0; x < x1; ++x, ++x_temp) {
.....        area.put_pixel(fractal_data_array[x_temp][y_temp]);
.....    }
.....}
```

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Worker B

Worker D

Worker C

Worker E

## Inner arena (internal tbb::parallel\_for())

```
cpu_arena = new tbb::task_arena(<Number of CPU threads>);
cpu_arena->execute([&]{
    tbb::parallel_for(tbb::blocked_range2d<int>(y0, y1, inner_grain_size, x0, x1, inner_grain_size),
        [&](tbb::blocked_range2d<int>&r){
            int x0 = r.cols().begin(), y0 = r.rows().begin(), x1 = r.cols().end(), y1 = r.rows().end();
            drawing_area.area(off_x + x0, off_y + y0, x1 - x0, y1 - y0, dm);
            for(int y = y0; y < y1; ++y){
                area.set_pos(0, y - y0);
                int x;
                color_t pixels_colors[8];
                for(int x = x0; x < x1; ++x){
                    area.put_pixel(calc_one_pixel(x, y, tmp_max_iterations, tmp_size_x, tmp_size_y, tmp_magn, tmp_cx, tmp_cy, 255));
                }
            }
        });
});
```

# Results



## Hottest GPU Computing Tasks

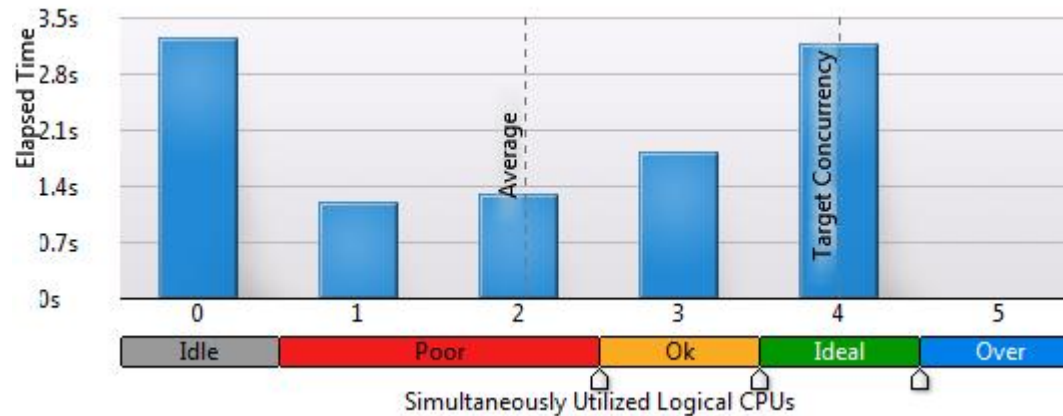
This section lists the most active computing tasks in your application running on the GPU.

Computing Task (GPU)	Global Size	Local Size	Average Time	Instance Count	SIMD Width	Total Time
render_rect_fractal\$parallel@323	99 x 100	1 x 4	0.314s	10	[Unknown]	3.142s
render_rect_fractal\$parallel@323	100 x 99	4 x 1	0.502s	5	[Unknown]	2.509s
render_rect_fractal\$parallel@323	100 x 100	1 x 4	0.257s	5	[Unknown]	1.284s

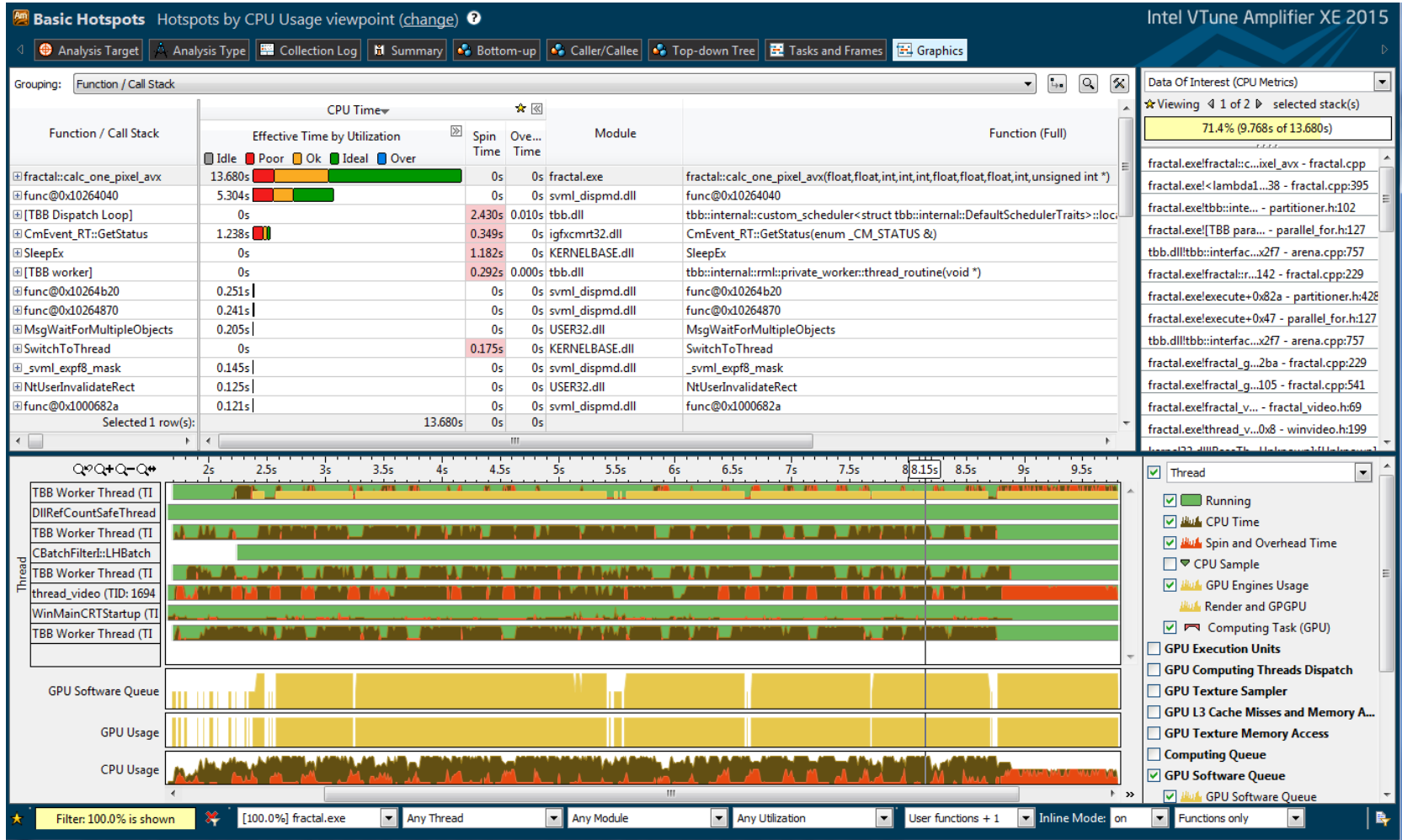
## GPU Usage

This section shows the time used by GPU engines.

GPU Engine	GPU Time
Render and GPGPU	6.959s

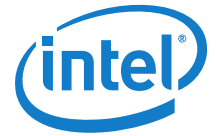


# Results (Graphics view)



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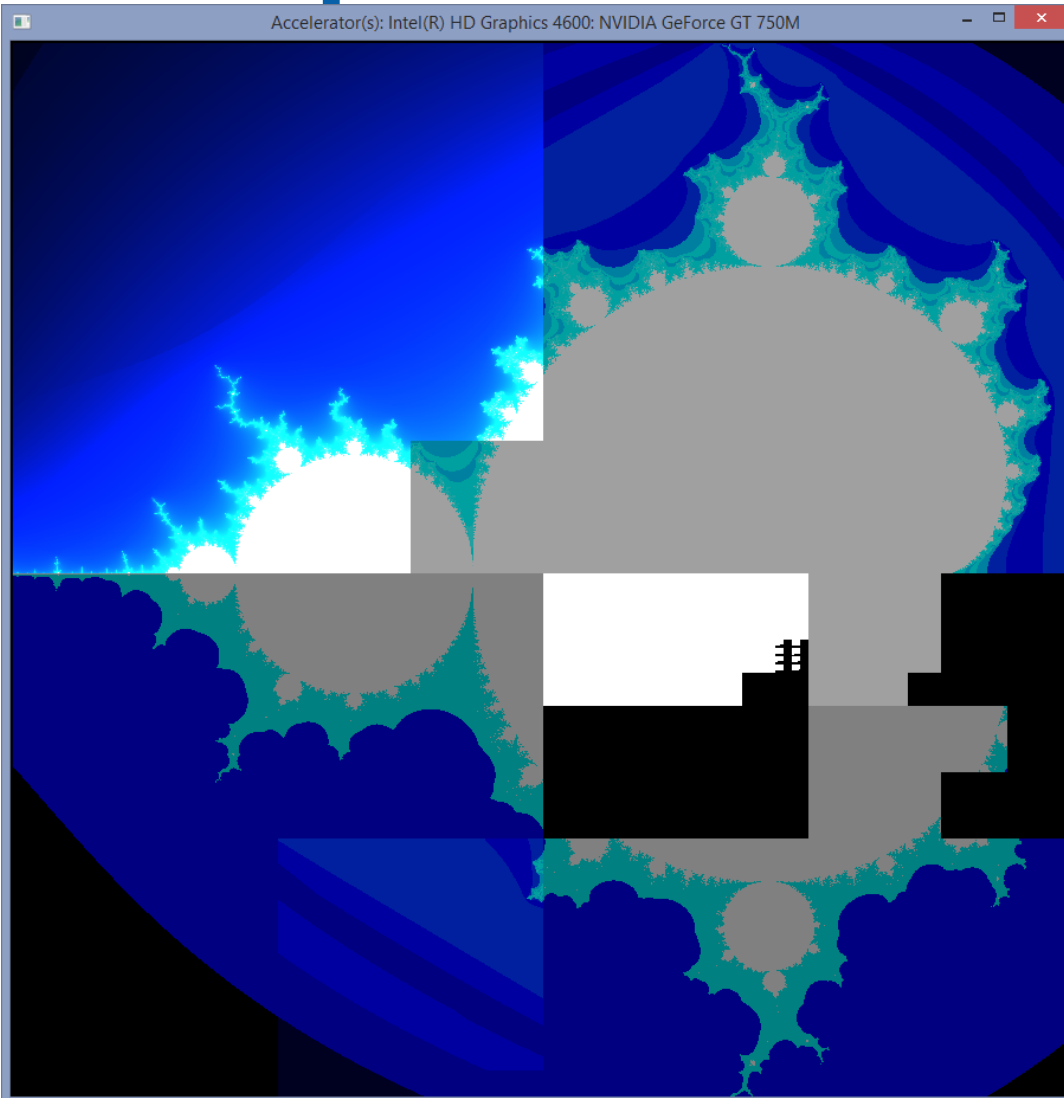
# Tomorrow?



Can you application utilize all resources efficiently?

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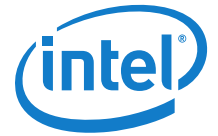
# Backup



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# Conclusion



## **Scale productive**

Tune and debug for more cores and nodes

## **Scale effectively**

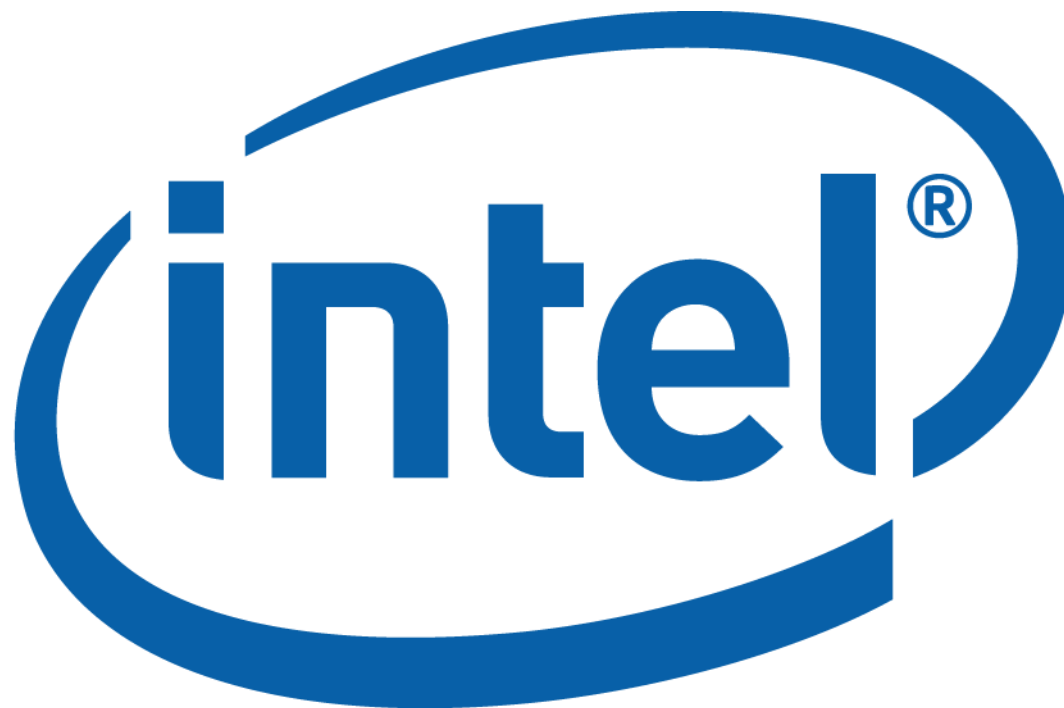
Keep performance

## **Scale for the future**

Multicore today, Many-core tomorrow

**Intel® Parallel Studio XE:** The Suite for developing of applications for shared and distributed memory models

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# Software

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