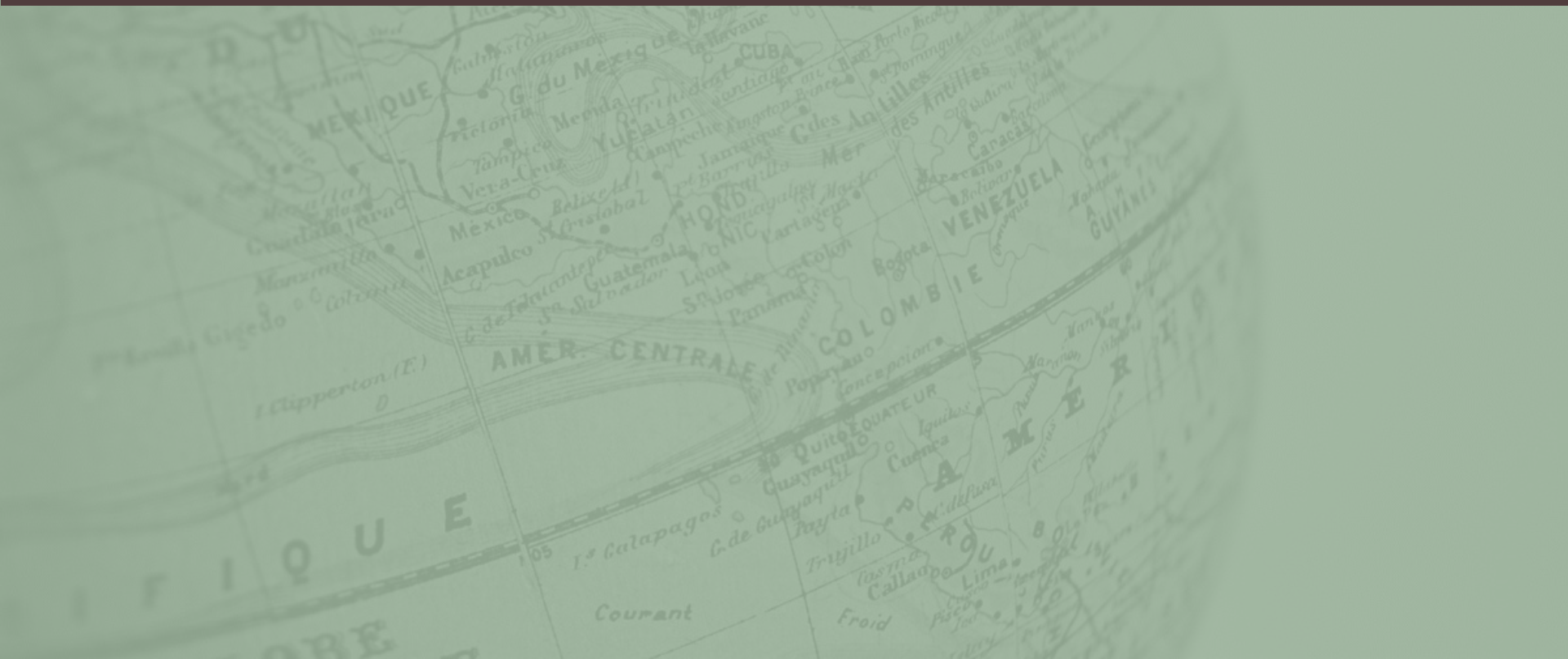


# OPEN CL ACCELERATED SIMPLIFIED GENERAL PERTURBATIONS 4 ALGORITHM

Juan Andres Fraire, Pablo Ferreyra, and Carlos Marques

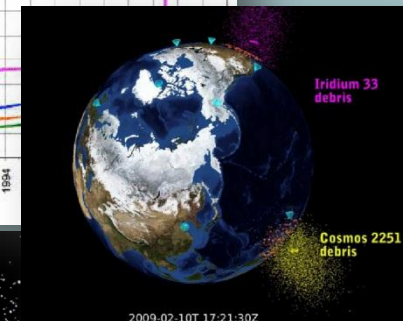
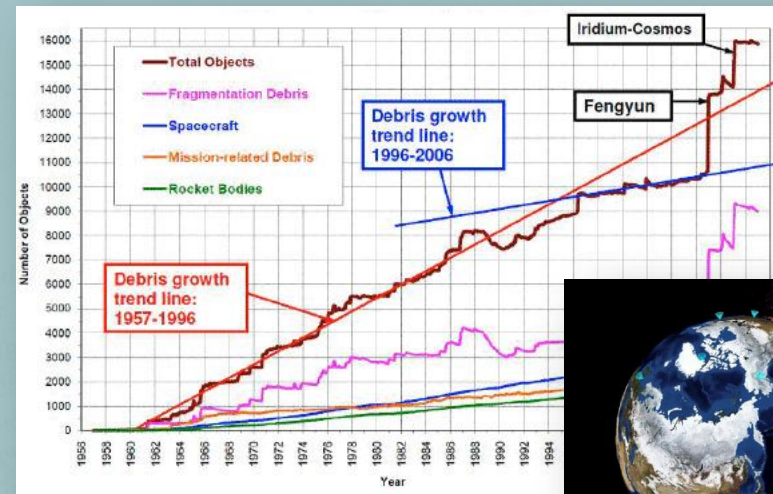


# PROBLEM DESCRIPTION

- The number of space objects such as satellites, spacecraft, and debris are increasing significantly.
  - 2007: Chinese anti-satellite missile test
  - 2009: Iridium-33 collision with Cosmos
- ISS crew forced to run to escape capsule due to prediction failure



**Need for better tracking and prediction systems!**



# CURRENT APPROACH

More  
Tracking  
Stations

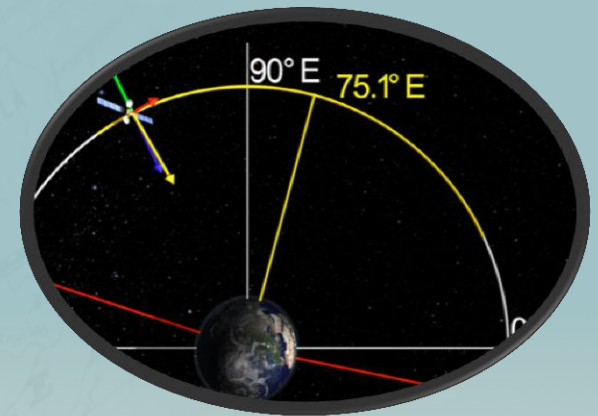


Better  
Propagation  
Mechanisms



Too Expensive!

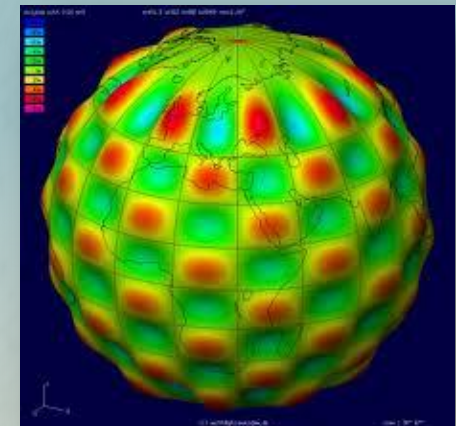
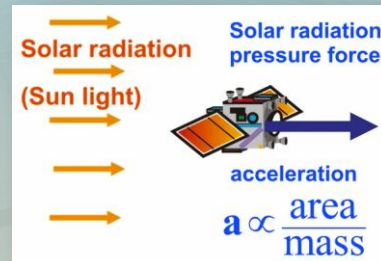
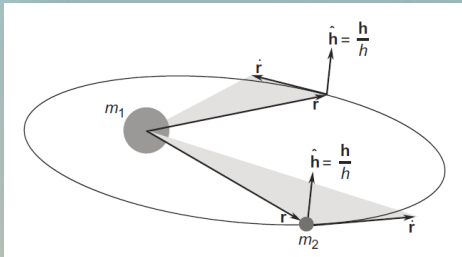
Space Tracking  
organizations:  
**Air Force Space  
Command (AFSCN)**  
&  
**Others...**  
Permanently track and  
predicts space activity



We go for this  
one!

# SATELLITE PROPAGATORS

- Basically, they tell us when and where an orbiting object will be in the future
- Several perturbations affects objects trajectories:
  - Non-uniform gravitation field (“J” Coefficients)
  - Atmospheric Drag
  - Sun Radiation Pressure
  - 3<sup>rd</sup> Body (Sun, Moon, Venus, etc)



# SATELLITE PROPAGATORS

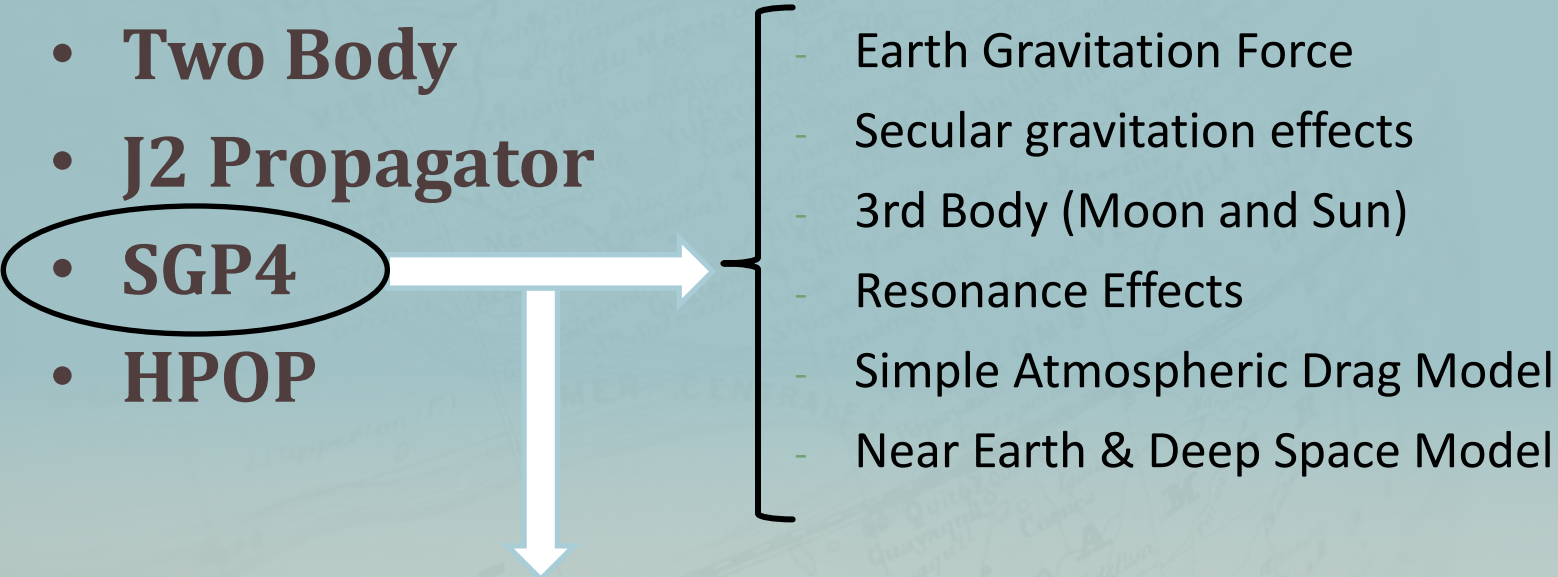
- Different propagators accounts for different perturbations effects:

- **Two Body**

- **J2 Propagator**

- **SGP4**

- **HPOP**

- 
- A diagram illustrating the relationship between satellite propagators and the perturbations they account for. On the left, a list of propagators includes 'Two Body', 'J2 Propagator', 'SGP4', and 'HPOP'. The 'SGP4' entry is circled in black. A white arrow points from the 'SGP4' circle to a large black bracket on the right. This bracket encompasses a list of perturbations: Earth Gravitation Force, Secular gravitation effects, 3rd Body (Moon and Sun), Resonance Effects, Simple Atmospheric Drag Model, and Near Earth & Deep Space Model. Additionally, a white arrow points downwards from the 'SGP4' circle to a quote at the bottom of the slide.
- Earth Gravitation Force
  - Secular gravitation effects
  - 3rd Body (Moon and Sun)
  - Resonance Effects
  - Simple Atmospheric Drag Model
  - Near Earth & Deep Space Model

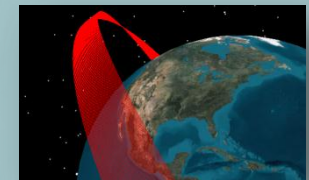
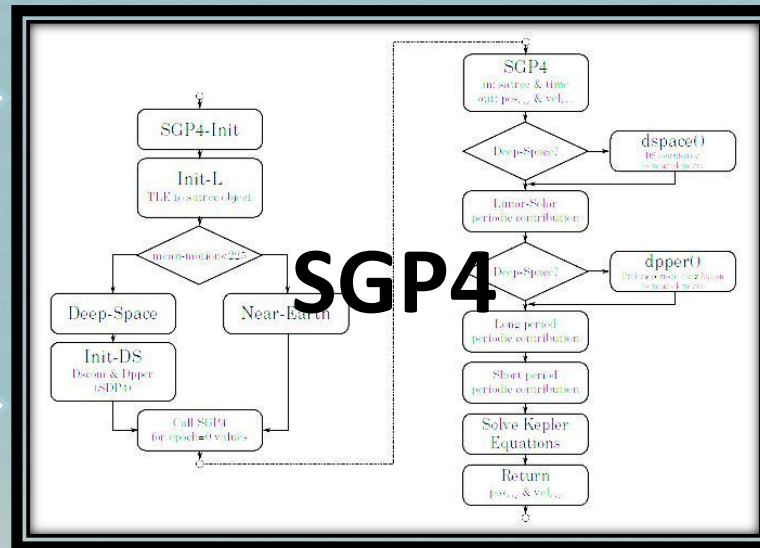
*“Publicly available and widely used because of its good performance/precision for tracking purposes”*

# SGP-4 PROPAGATOR

- SGP4 Algorithm implies complex trigonometric calculations, but essentially:

Initial Orbital  
Parameters  
(TLE)

Time from  
Initial  
parameters  
(T)



Position Vector  
&  
Velocity Vector  
In time T

“Earth Centered Inertial Coordinate Reference System”

# SGP-4 PROPAGATOR IN OPEN-CL

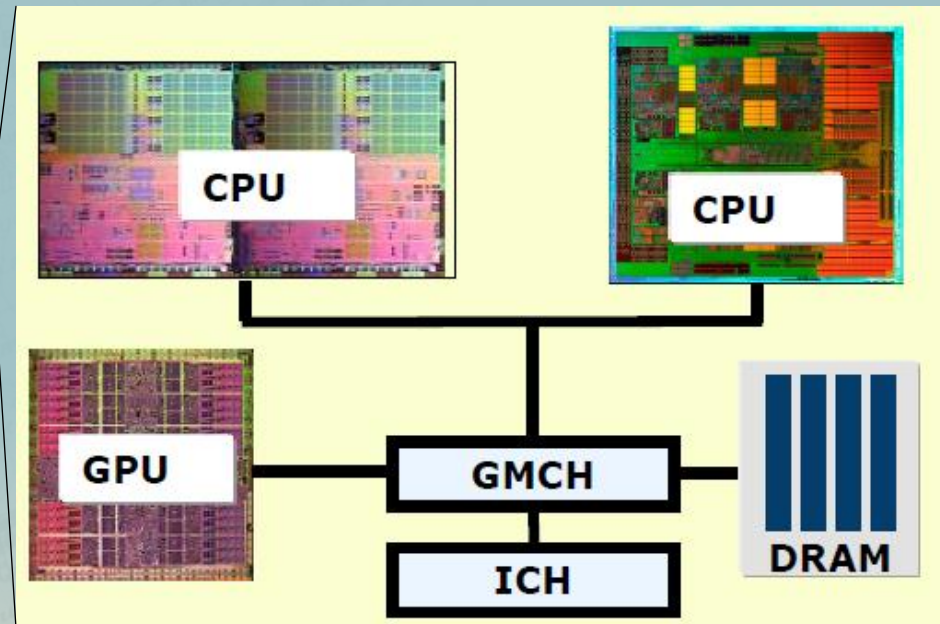
- We implemented this algorithm in *Open-CL* to improve the execution performance in an *heterogeneous system*



“A collection of CPUs, GPUs, DSP, FPGA, and any processing element in a given platform”



Several orbiting objects propagated in parallel in many devices!



GMCH = graphics memory control hub,  
ICH = input/output control hub

# ABOUT OPEN-CL

- Open-CL is a **cross-platform, cross-operating system, cross-vendor open standard**
- Oriented to programming a collection of **CPUs, GPUs, DSPs, FPGAs**, and others, even **cell-phones** and **mainframes!**
- Allows to assign “**tasks**” (named **Kernels**) to the most proper device
- Exploits **System** and **Device** parallelism at the same time



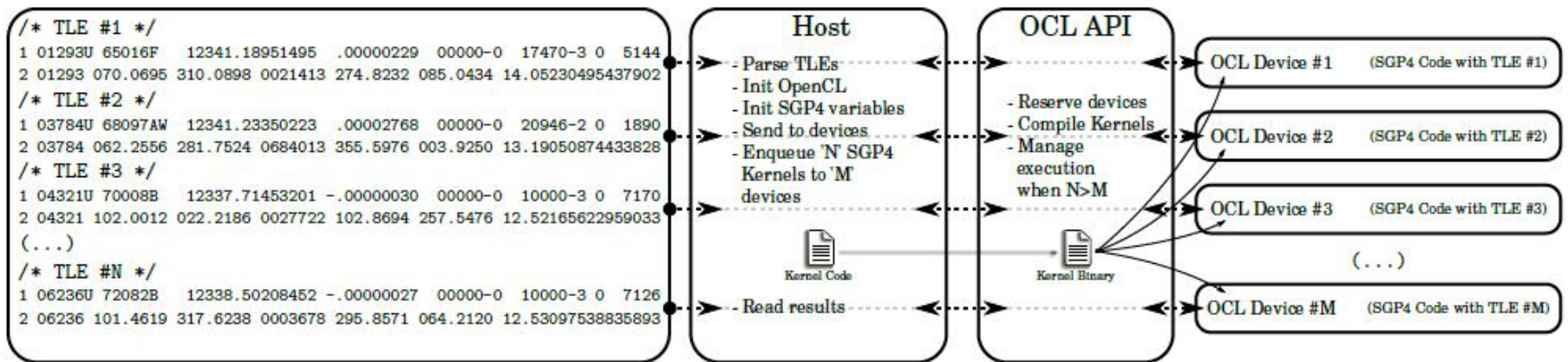


# HOW WE DID IT

TLE Files defines the initial conditions of many orbiting objects



An Open-CL Host Initializes and distribute the work load to available hardware. It also read the results and store or show in the screen



OpenCL APIs are available for Linux, Windows, and OSX

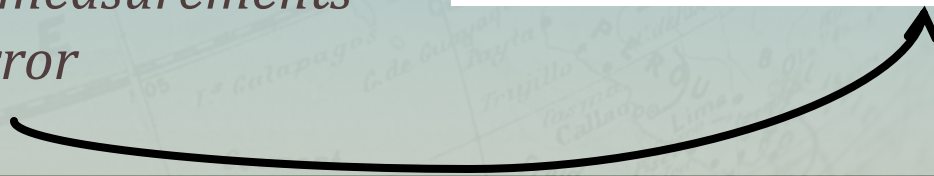
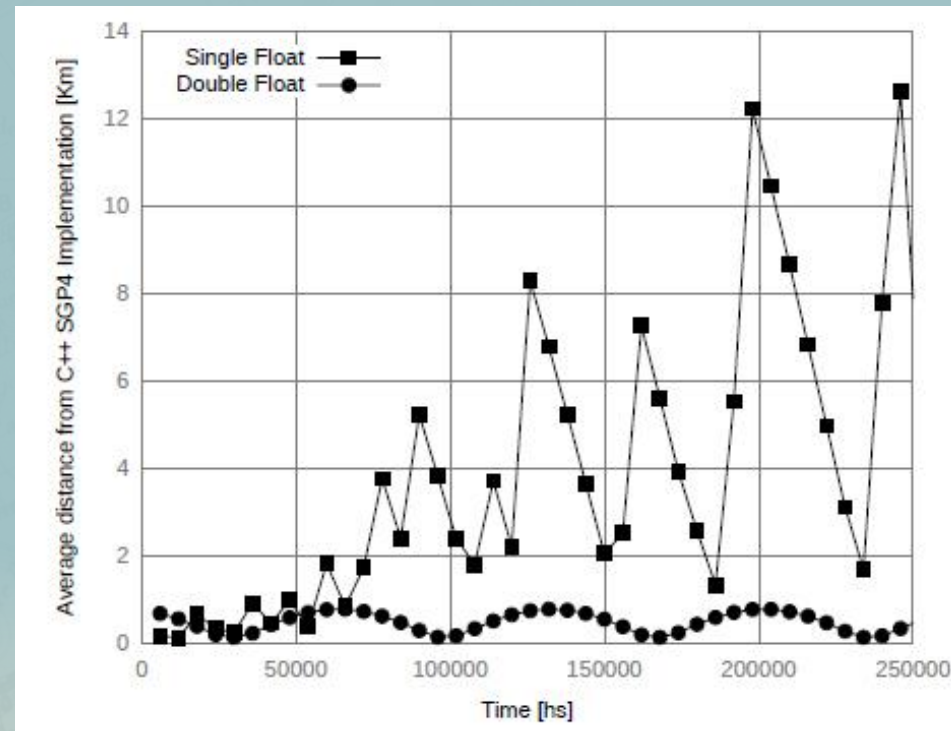
We tested on CPUs and GPUs devices

# WHAT WE CONSIDERED: PRECISION

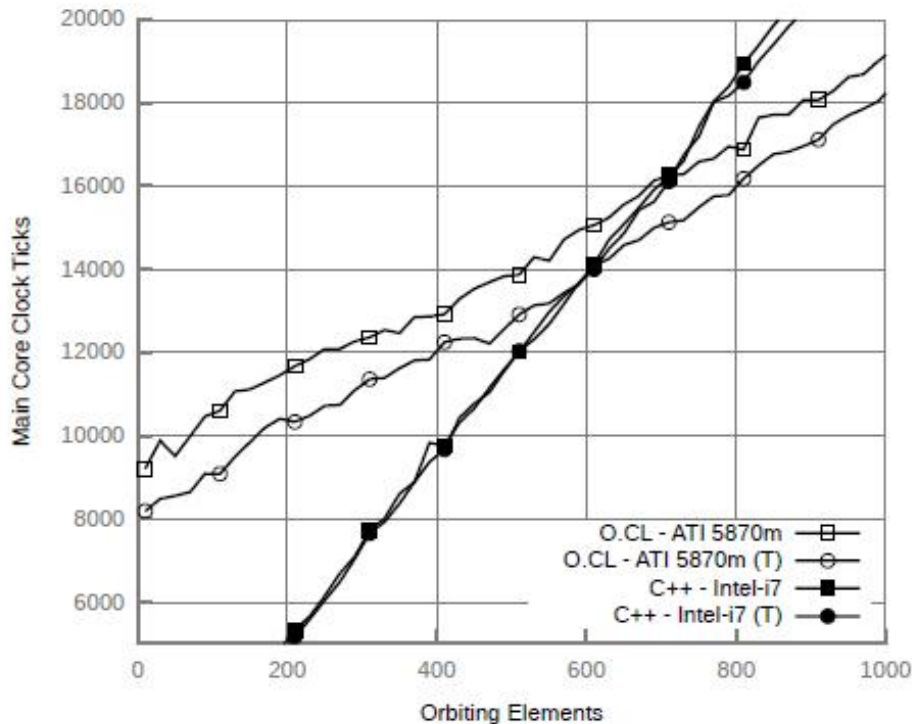
- Depending on the available device, double floating point calculation might or not be available...



*We provide two versions of SGP-4 Kernel to better adapt the underlying hardware with no considerable measurements error*



# WHAT WE CONSIDERED: TIME

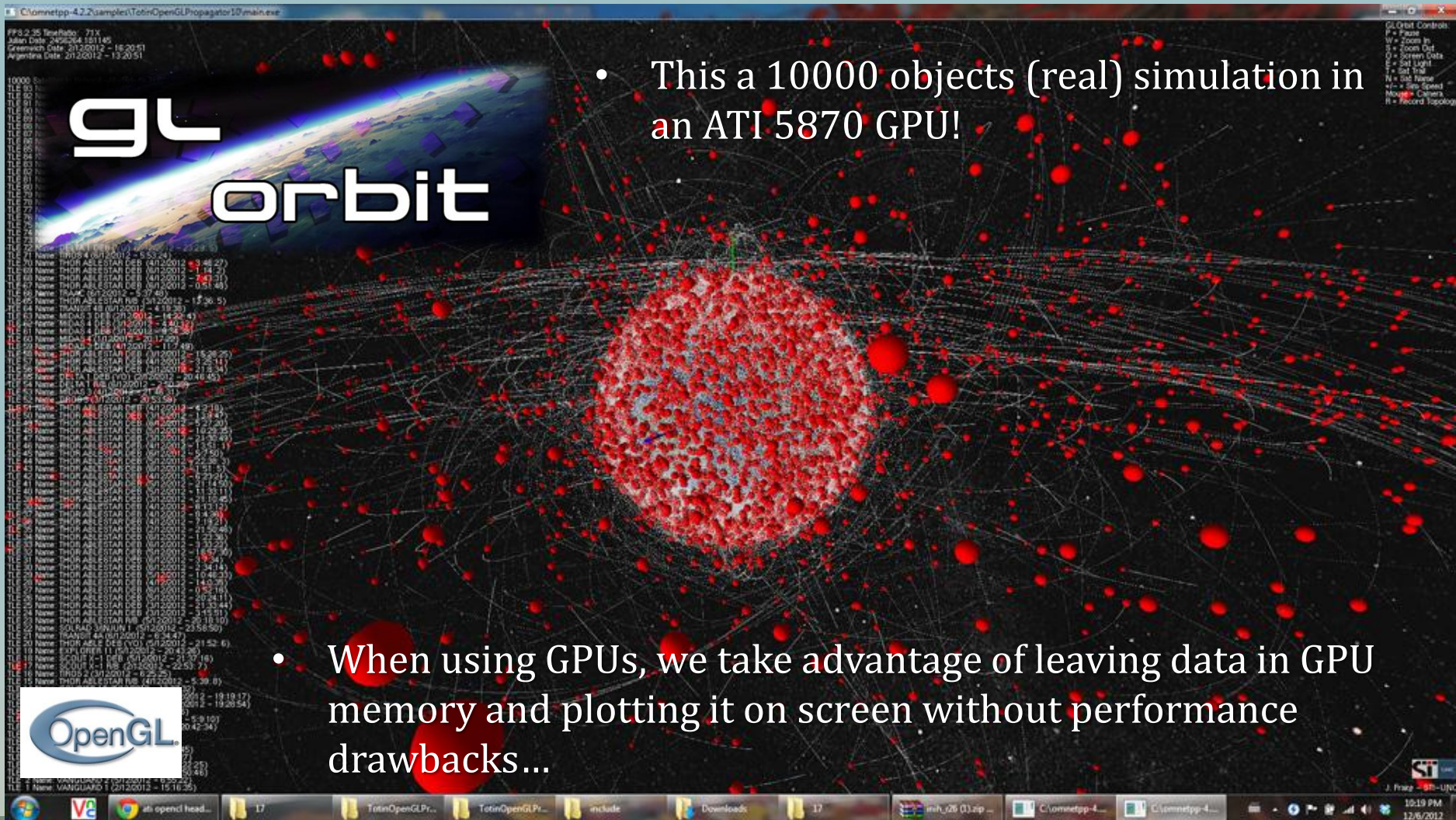


- Also we allow to advance time (**T**) within the same Kernel or from the Host Code



*Advancing the time in the Kernel limits propagation control but delivers increasing performance as it drastically reduces memory transfers to the device*

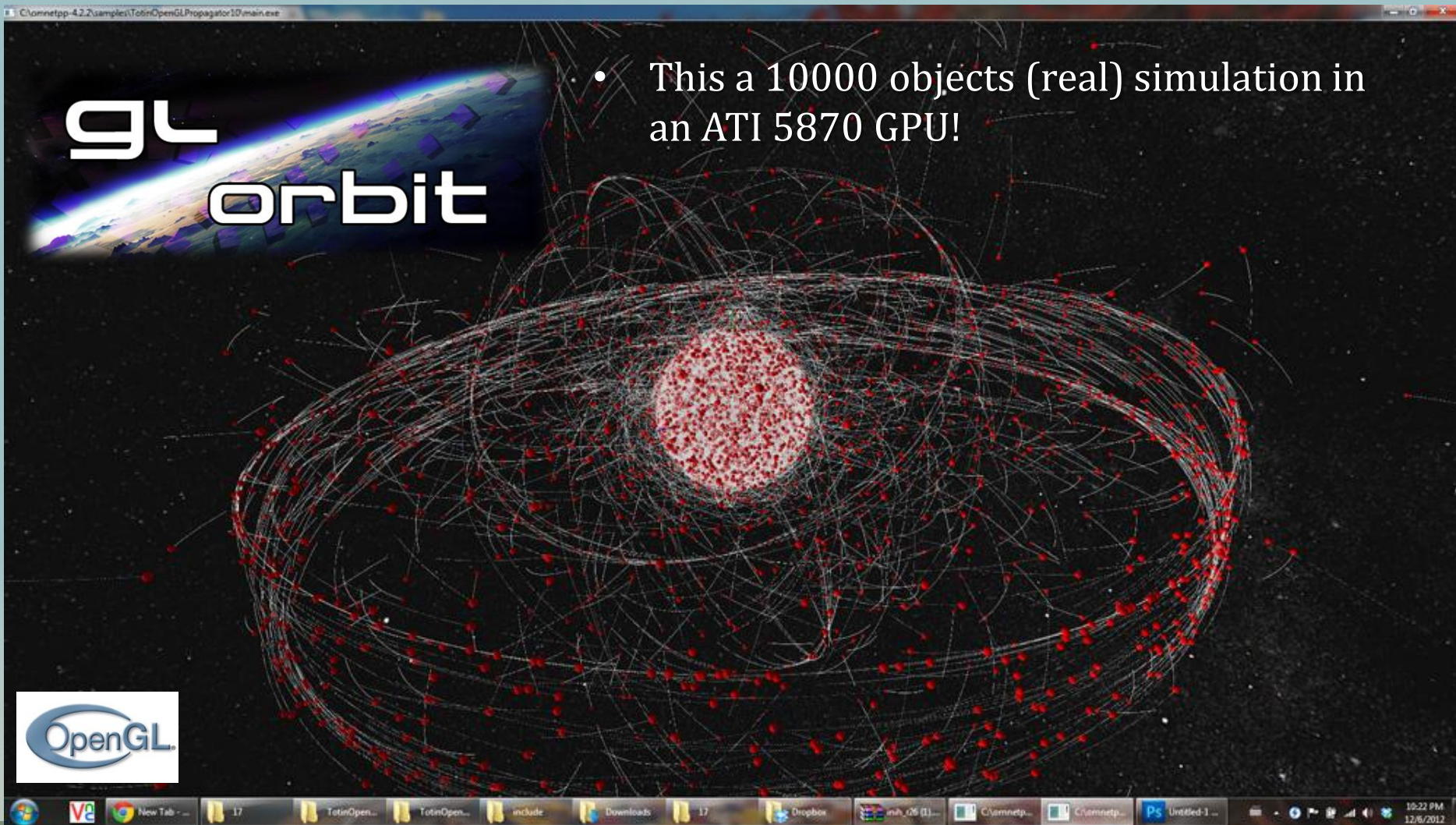
# WHAT WE CONSIDERED: GRAPHICS



The screenshot shows a 3D simulation window titled "glorbit". The main view displays a dense field of red spheres of varying sizes, with a large, bright, textured cluster in the center. The background is a dark space with a curved horizon line on the left. The window title bar reads "C:\omnetpp-4.2.2\samples\TetraOpenGLPropagator\10\main.exe". The top-left corner shows system information: "FPS: 2.35 Time: 71x", "Jan 01, 2012 18:25:18", "Greenwich Date: 20120102 - 18:20:51", and "Argentina Date: 20120102 - 13:20:51". The top-right corner has a control menu: "GL Orbit Controls", "F = Freeze", "W = Zoom In", "E = Zoom Out", "O = Screen Data", "L = Sat Light", "T = Sat Trail", "M = Sat Mass", "N = Site Speed", "Mouse = Camera", and "R = Record Topology". The bottom-left corner features the "OpenGL" logo. The bottom-right corner shows the Windows taskbar with the system tray displaying "12:19 PM" and "12/6/2012".

- This a 10000 objects (real) simulation in an ATI 5870 GPU!
- When using GPUs, we take advantage of leaving data in GPU memory and plotting it on screen without performance drawbacks...

# WHAT WE CONSIDERED: GRAPHICS



The screenshot displays a Windows desktop environment. The primary focus is a window titled "glorbit" which shows a 3D simulation of a celestial body with a complex, chaotic orbit system. The simulation features a central cluster of red particles and numerous intersecting grey orbital paths. In the upper left corner of the window, the text "glorbit" is displayed in a stylized white font. A bullet point is positioned to the left of the text "This a 10000 objects (real) simulation in an ATI 5870 GPU!". The Windows taskbar at the bottom shows several open applications, including "New Tab", "Downloads", "Dropbox", "msn\_06 (1)", "C:\amnetp...", "C:\amnetp...", and "Ps". The system tray on the right indicates the time as 10:22 PM on 12/8/2012.

- This a 10000 objects (real) simulation in an ATI 5870 GPU!

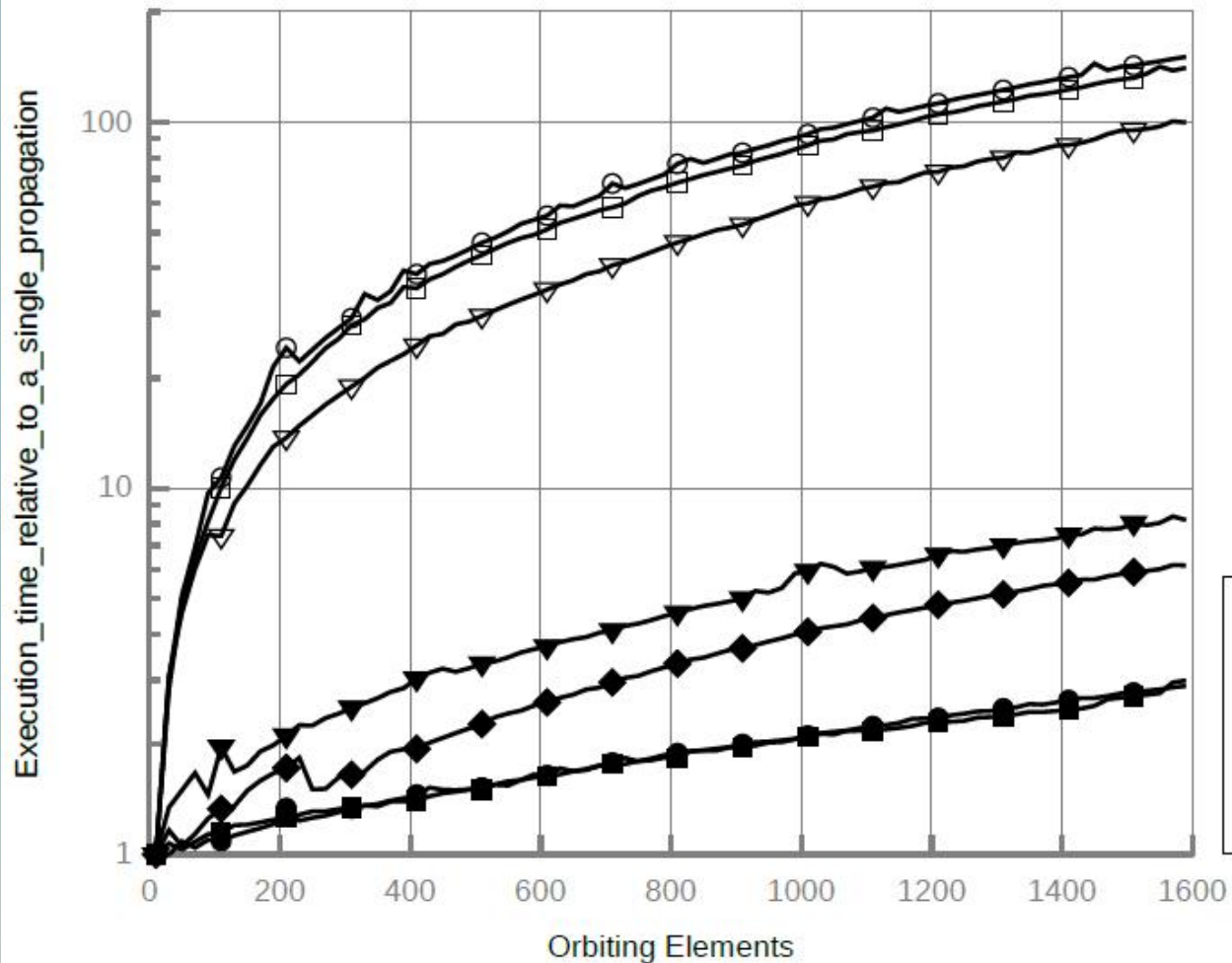
# PERFORMANCE EVALUATION

- As Open-CL executes in almost **any underlying hardware**, we evaluated our implementation in several processing devices:

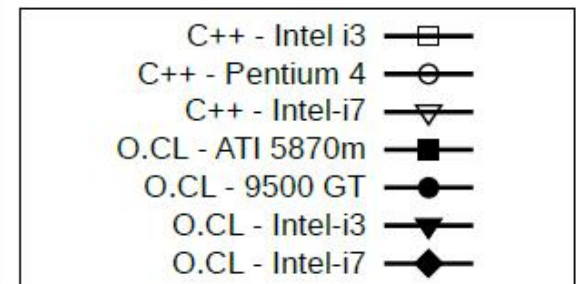
Vendor	Device	Type	Platform Version	Platform Vendor	Comp. Units	Max Dim.	Max WI in a Dim.	Max WG Size	Max Clk Freq	Addr. Bits	Global Mem Size	Local Mem Size	Double F. Point
Intel(R)	Core(TM) i7 CPU Q 720 @ 1.60GHz	CPU	OpenCL 1.1 AMD-APP-SDK-v2.5	Advanced Micro Devices, Inc.	8	3	1024	1024	1596MHz	32	2GB	32KB	Yes
Intel(R)	Core(TM) i3-2330M CPU @ 2.20GHz	CPU	OpenCL 1.1 LINUX	Intel(R) Corporation	4	3	1024	1024	2200MHz	64	4GB	32KB	Yes
AMD(R)	ATI HD 5870 Mobility	GPU	OpenCL 1.1 AMD-APP-SDK-v2.5	Advanced Micro Devices, Inc.	10	3	256	256	700MHz	32	1GB	32KB	No
NVIDIA(R)	GeForce 9500 GT	GPU	OpenCL 1.1 CUDA 4.1.1	NVIDIA Corporation	4	3	512	512	1350MHZ	32	512MB	16KB	No

- We propose a **1600** orbiting element satellite scenario with a position call each hour for each element for a complete year → this is **8760\*1600** kernels executions!

# RESULTS



**Open-CL outperforms standard non-parallel optimized C++ compilations in all cases, while extending the available hardware to perform the propagation tasks**



# CONCLUSION

- We implemented the **SGP-4** Algorithm in **Open-CL**
- This allows to better use powerful COTS hardware in a **transparent** yet **efficient** fashion
- No significant calculation errors are evidenced for considering double floating point precision



- **Performance improvement** is always welcomed in an ever **increasing debris tracking system**



# GL-ORBIT VIDEO

