■ Example 5: Mapping the sky:

(a) The European Space Agency's satellite ***Hipparcos***:

The following extract from the ESA web pages (http://sci.esa.int/content/doc/40/14400_.htm) gives a flavour of what's involved:

"Unique to Europe Hipparcos was the very first space mission for measuring the positions, distances, motions, brightness and colours of stars - for ***astrometry***, as the experts call it. ESA's Hipparcos satellite pinpointed more than ***100 000 stars***, 200 times more accurately than ever before. As astrometry has been the bedrock of the study of the Universe since ancient times, this leap forward has affected every branch of astronomy".

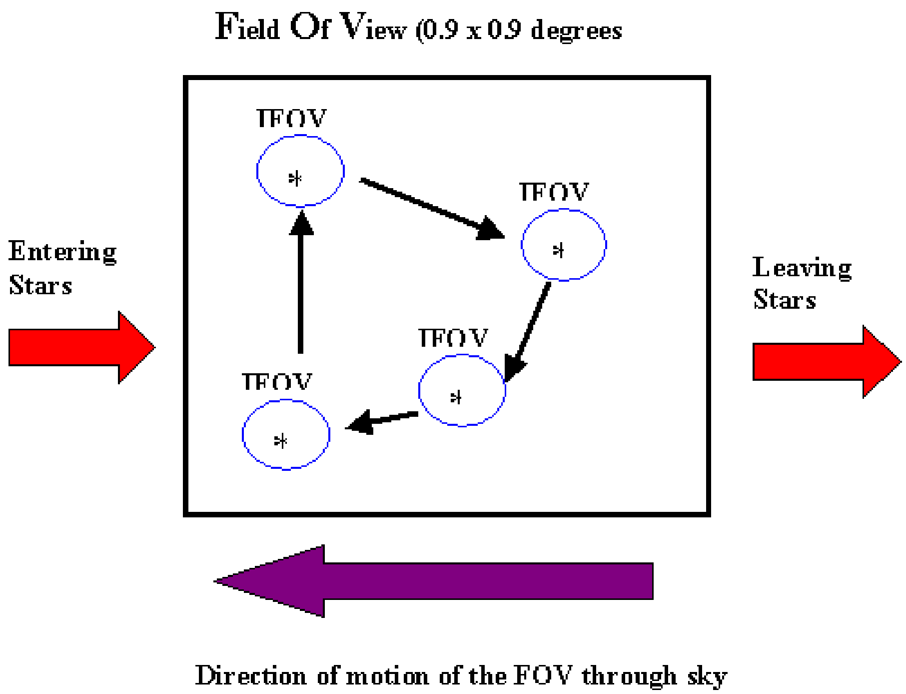
Essentially, Hipparcos consisted of a specialised telescope operating in Space.

(b) Simulations of the ***Hipparcos*** "payload" - one particular problem:
Simulation is a very powerful tool in the design phase of any complex engineering project.

A familiar example is the development of a road network - it is far easier and cheaper to use computers to simulate different scenarios rather than building actual systems on a trial and error basis!

Similarly, it was necessary to simulate the Hipparcos instrumentation to determine optimal values of parameters such as the size of the telescope's field of view (FOV).

A particular problem was to model the errors incurred in positioning the "instantaneous field of view" (IFOV):



Essentially, the IFOV was a kind of "spotlight" which was moved cyclically between the stars currently in the full field of view.

There were various sources of errors in moving the IFOV from one star to another. In particular, measurements were less accurate if a star was "off centre".

The purpose of simulation was to model this system, to quantify the errors involved, to assess the impact of parameters such as the spinning speed of the FOV, to give guidance on how to improve the design, etc.

The simulation software had different elements - for example, one module was to simulate the flow of stars entering the field of view.

(c) The size of the "***number crunching***" tasks that can arise:

(I) As mentioned above, the Hipparcos satellite pinpointed more than100 000 stars. In fact, for each star there are 5 quantities to be determined:

Position (latitude, longitude), Proper motions (speed in latitude and longitude) and

Parallax (distance from observer).

Thus, there were a total of about 500,000 unknowns to be determined.

(II) At present, ESA is involved in planning a successor mission to Hipparcos, called ***Gaia***.
"GAIA will measure more than ***1 billion*** stars in a global stellar census of our Galaxy and its nearest neighbours" (see http://astro.estec.esa.nl/SA-general/Projects/-GAIA/gaia.html).
Thus, Gaia will need to determine about ***10000 times more unknowns*** than Hipparcos. This will require extensive use of distributed computing facilities.
It has been estimated that the equivalent of about 10^{19} floating-point operations (FLOP) will be involved. The OSC CRAY SV1 computer has a peak performance of about 32 GFLOPS (i.e. per second) so that machine would take about 10 years operating non-stop and "flat out"! [G = Giga = 10^9]

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10^19 / (32 * 10^9) / 60 / 60 / 24 / 365.
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9.90931
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<u>(d) Hipparcos results in action</u>:

For those interested, there is an ESA web-site where results from Hipparcos can be viewed using software written in Java (http://astro.estec.esa.nl/-Hipparcos/hipparcos_java.html). Also, follow "research tools" link from http://astro.estec.esa.nl/Hipparcos/.