Bigger, Better, Faster POD

Session THPM1

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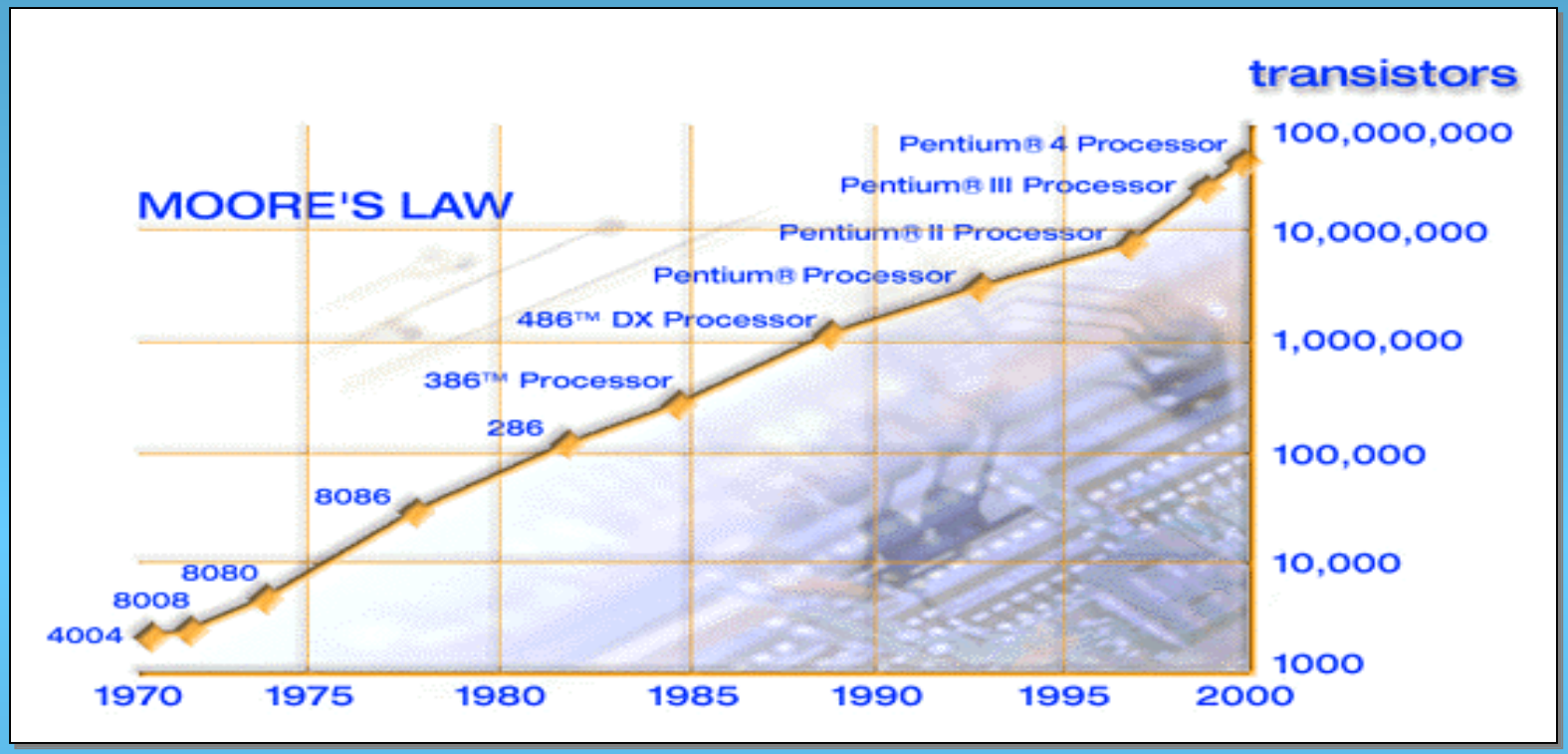
Introduction

- Large POD processes at the Analysis Centres are the basis of everything - the price tag attached to generating IGS products
- IGS product range has grown over the first 10 years and is likely to be extended further in the future
- Demands on IGS POD processes will grow substantially:
  - Network densification: *more stations = more data + more parameters*
  - GLONASS, Galileo: *more satellites = more data + more parameters*
  - LEO satellites: *higher data rate = more data + more parameters*
  - Short latency / real-time processing = *less time for each process*
- Computer hardware improves with time, but will this be sufficient to cope with the increasing demands of IGS?
- Are there other ways to constrain the processing load?

Bigger = Better ≠ Faster

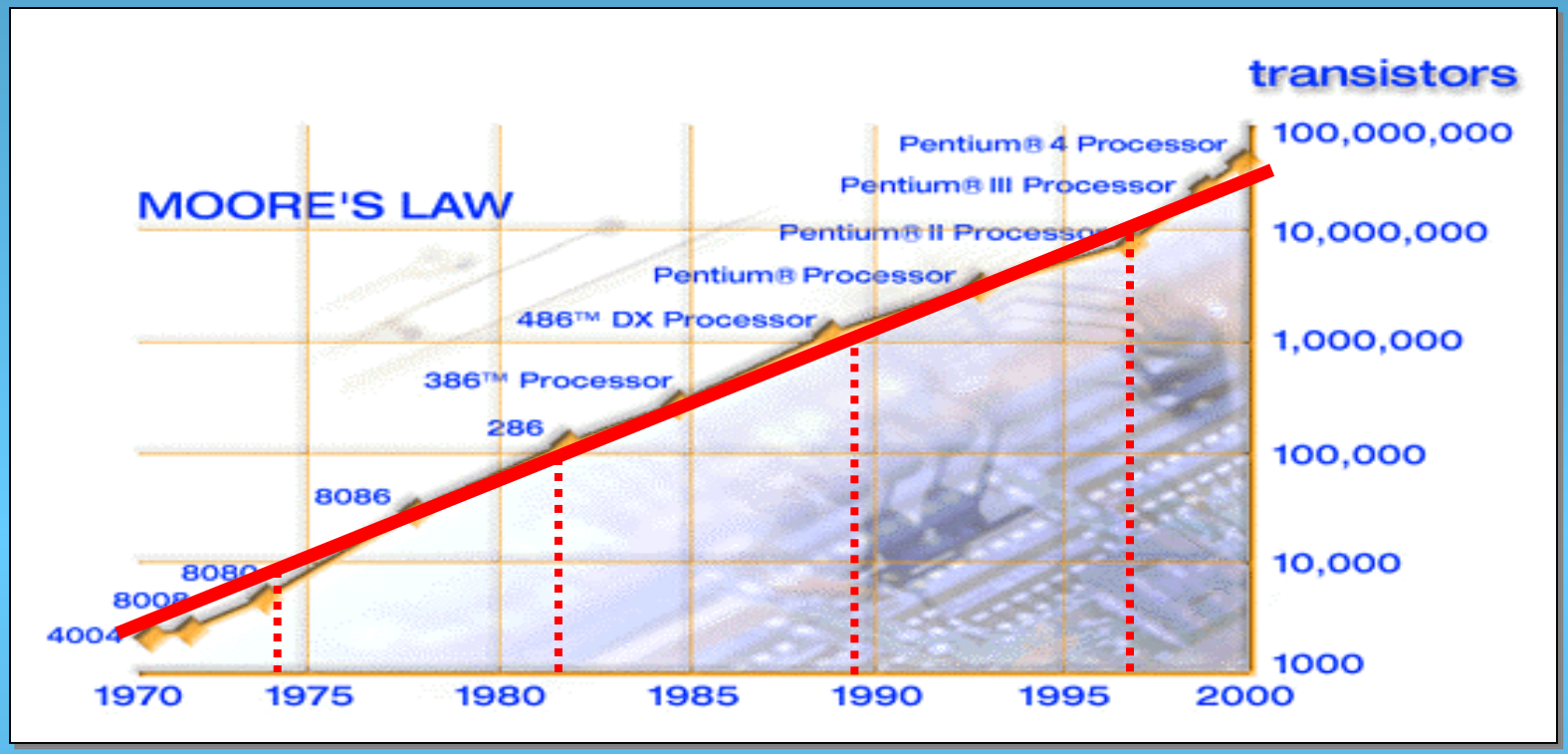
- Improvement of product quality or extension of product range typically leads to increase of POD size:
  - "better" and "bigger" tend to be equivalent
- Increase of size typically leads to longer run times:
  - "bigger" and "better" are equivalent to "*not* faster"
- IGS product range reflects this contradiction:
  - Ultra-rapids are fast, but less precise
  - Finals are most precise, but have long latency
  - Rapids are a compromise between "better" and "faster"
- Estimate of future processing demands will be attempted to assess if processing demands will remain within capabilities

Hardware developments (1)



- Computer performance figure of interest to IGS is processing time (CPU)
- Memory less critical (64 bit systems are coming…)

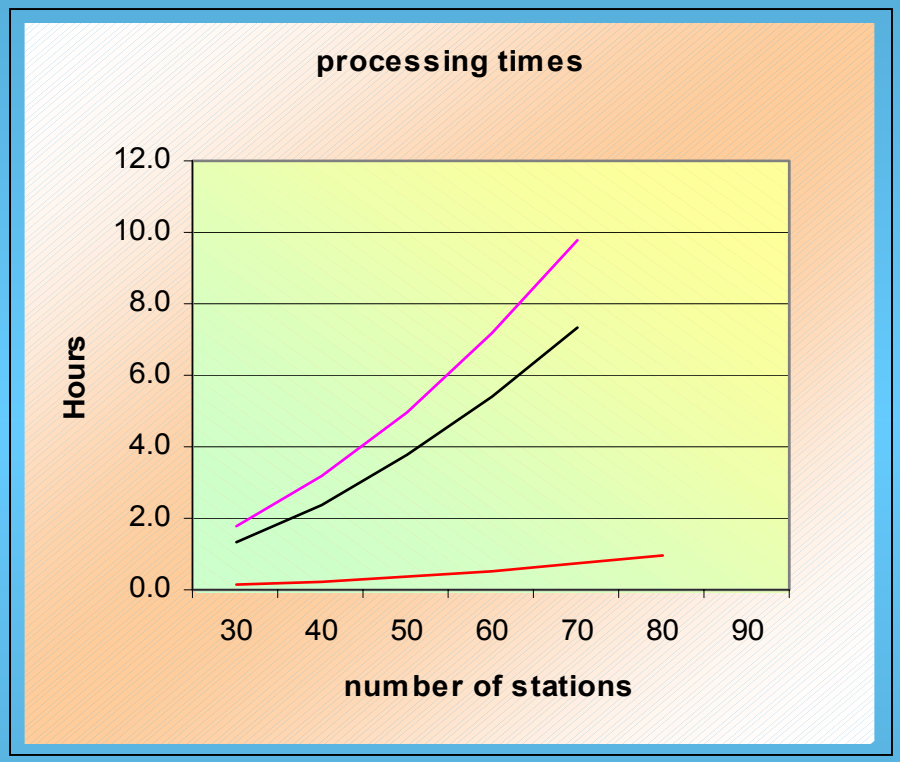
Hardware developments (2)



- Steady trend in CPU improvements:
  - Factor 10 more components per surface every 7.5 years
  - Processing speed grows slightly less (…heat problems)

Bigger & Better POD

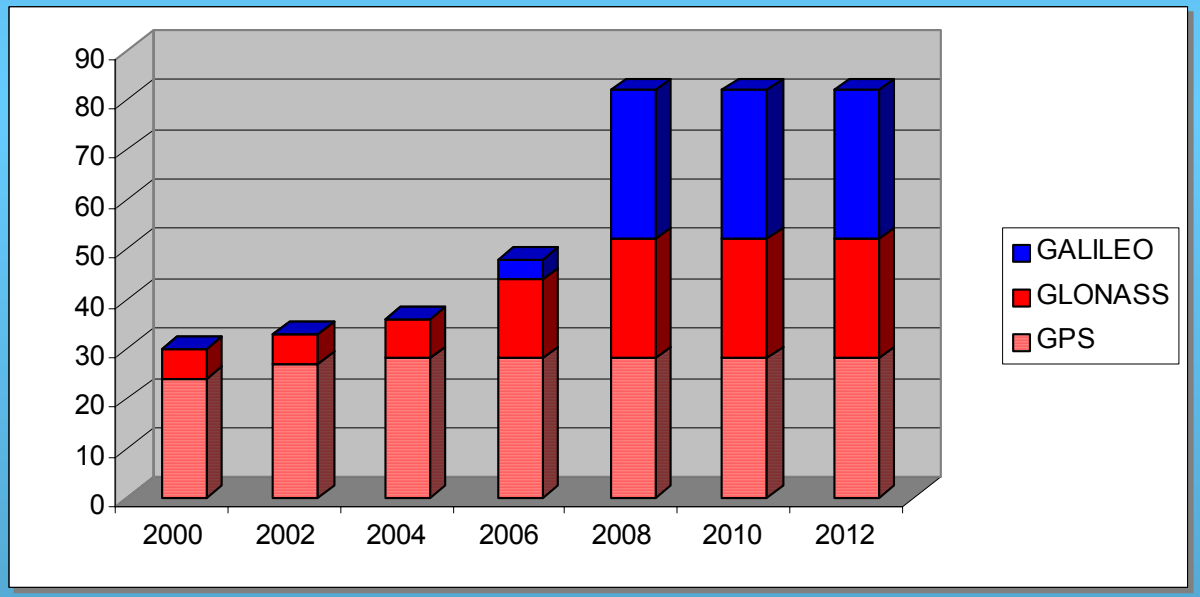
- Size of estimation process is typically determined by
  - Number of observations
  - Number of parameters
- Both numbers grow *at least linearly* with
  - number of GNSS satellites
  - number of stations
  - inclusion of LEO satellites
- Processing time is typically a cubic function of these three quantities



Number of GNSS satellites

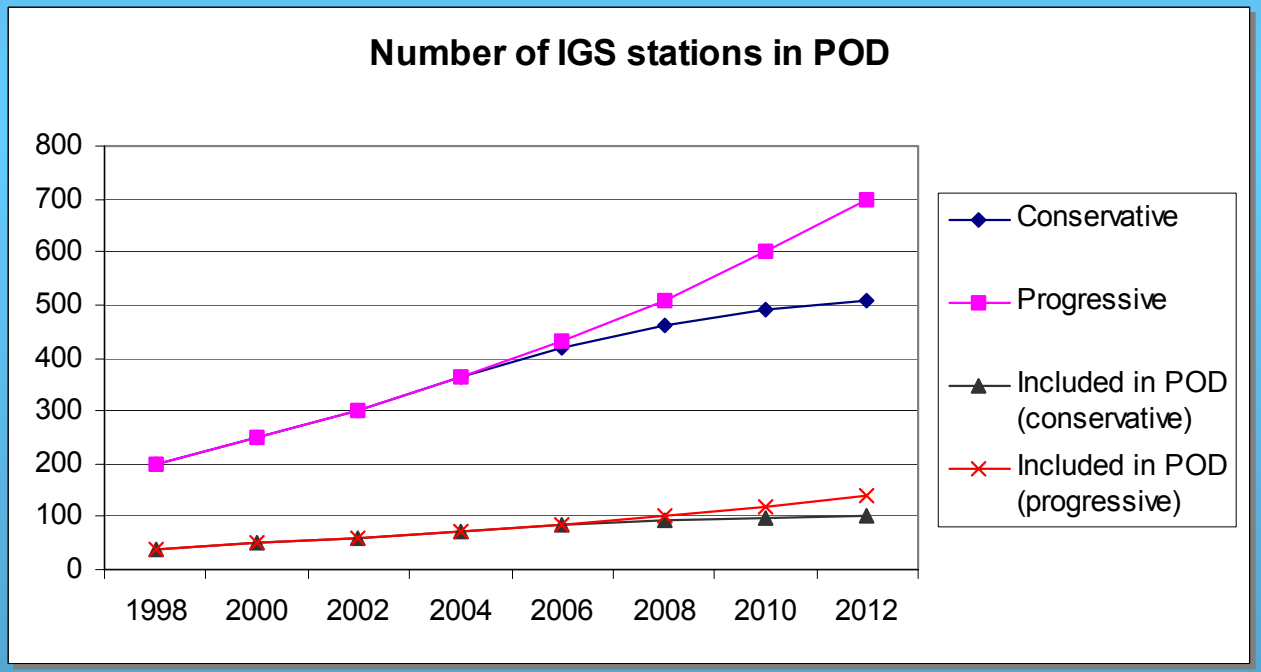
- Not all satellites may be included in a single process, but at least at level of combination solutions this would be useful
- The number of GNSS satellites of interest to IGS will grow sharply around 3 .. 6 years from now to:
  - **24 GLONASS**
  - **30 Galileo**
  - **28 GPS**

  Total 82



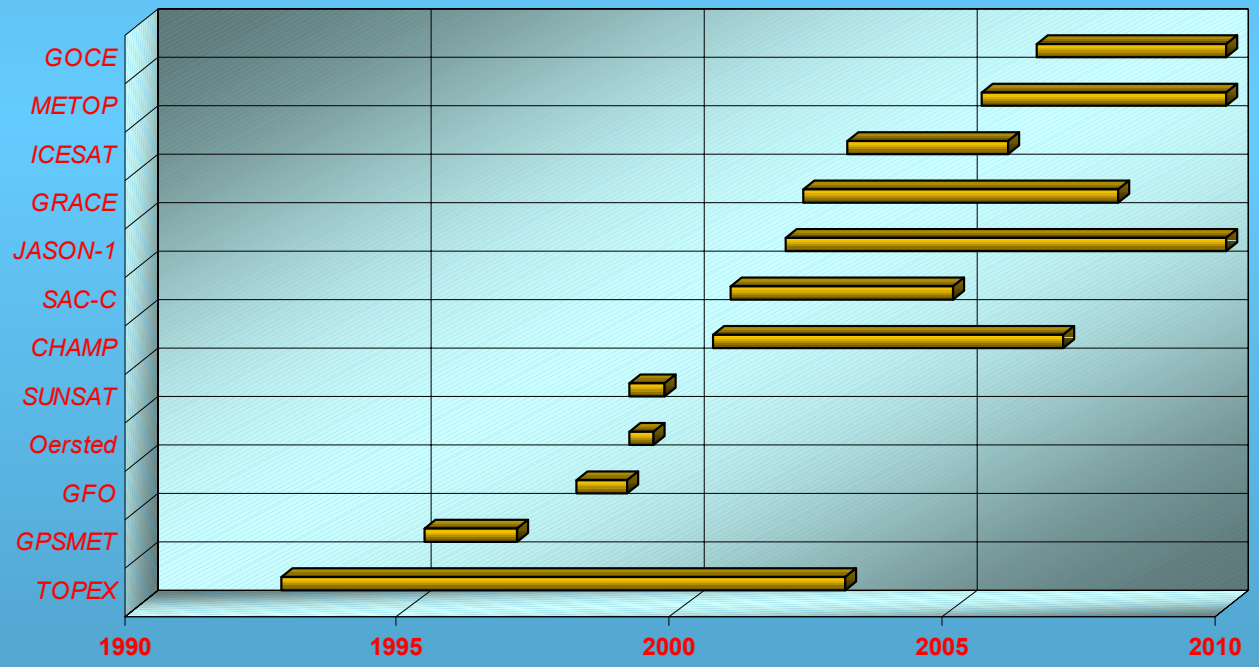
Number of ground stations

- Number of stations will grow but it is not clear how fast.
- Number of stations that needs to be included in a typical POD run is about 15 … 20 percent of total IGS network



Inclusion of LEO satellites

- LEO satellites require higher data rates: ~30 seconds instead of ~5 minutes would imply 10 times more data for given arc length!
- If GPS & station clocks are also needed at high rate:
  - first included LEO augments process size by about one order of magnitude
  - further LEO can use same clocks, but still add data + parameters



Estimated increase in POD size (1)

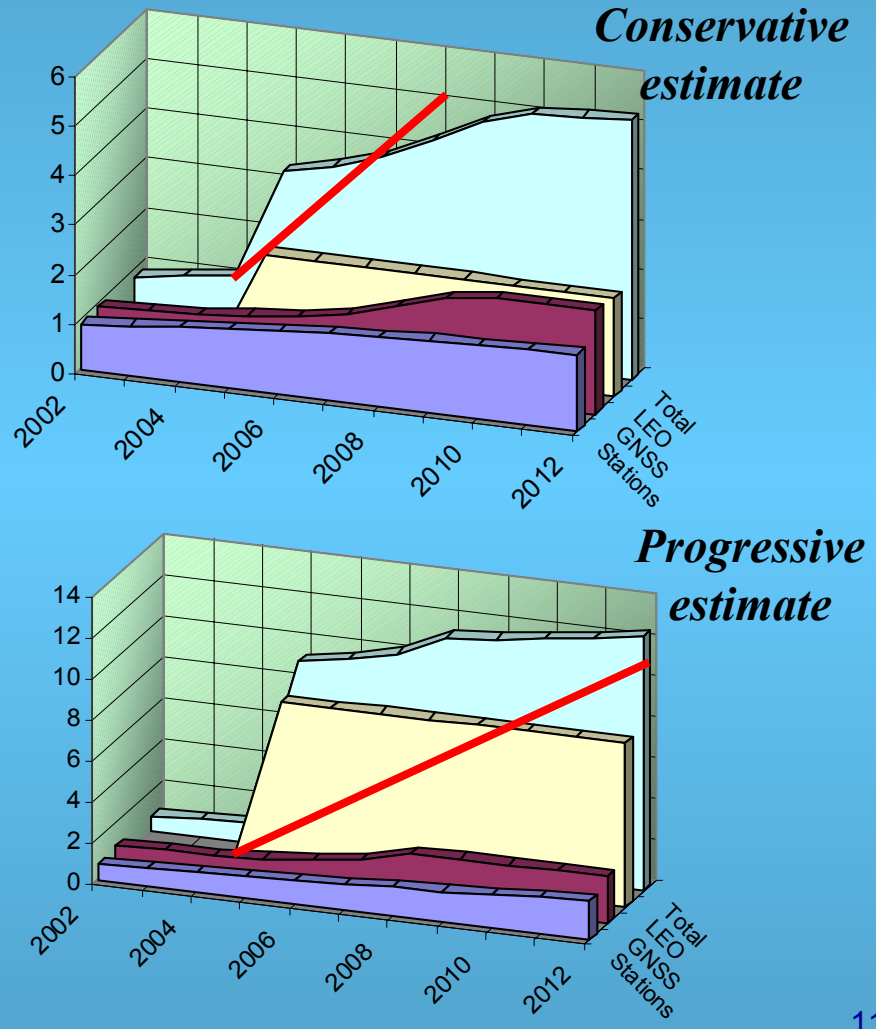
- Conservative and progressive estimates can be made of expected POD size
- Assumptions that will be used:
  - Process size grows only linearly with the number GNSS satellites
    - Conservative estimate: no GLONASS, Galileo complete by 2010
    - Progressive estimate: full GLONASS and Galileo by 2008
  - Process size grows only linearly with the number of ground stations
    - Conservative / progressive estimates as shown before
  - Inclusion of the first LEO augments process size by a constant factor
    - **Conservative estimate: factor 2**
    - **Progressive estimate: factor 8**
  - Any further LEO satellites are considered as just another ground station
    - …. in reality a LEO adds many more parameters than a ground station
- Number of stations and satellites is normalized by the 2004 situation to get a dimensionless growth factor for POD processing:

$$\frac{POD\ size}{size\ in\ 2004} = \frac{(number\ GNSS\ satellites)}{(28\ GNSS\ in\ 2004)} * \frac{(number\ stations + LEO)}{(70\ stations\ in\ 2004)} + Fac_{LEO}$$

Estimated increase in POD size (2)

- Increase of hardware performance buys a factor 10 over 8 years
- Conservative estimate: minor temporary problems
- Progressive estimate:

  LEO satellites cause major problems until ~2015
  - Parallel processing?
  - Shorter arc lengths?
  - Fewer stations?
- Reduction of latency has not yet been considered!



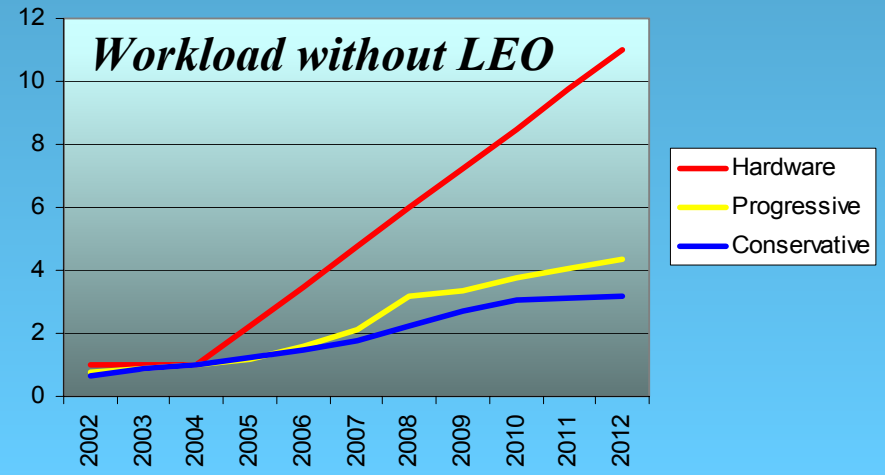
Faster POD (1)

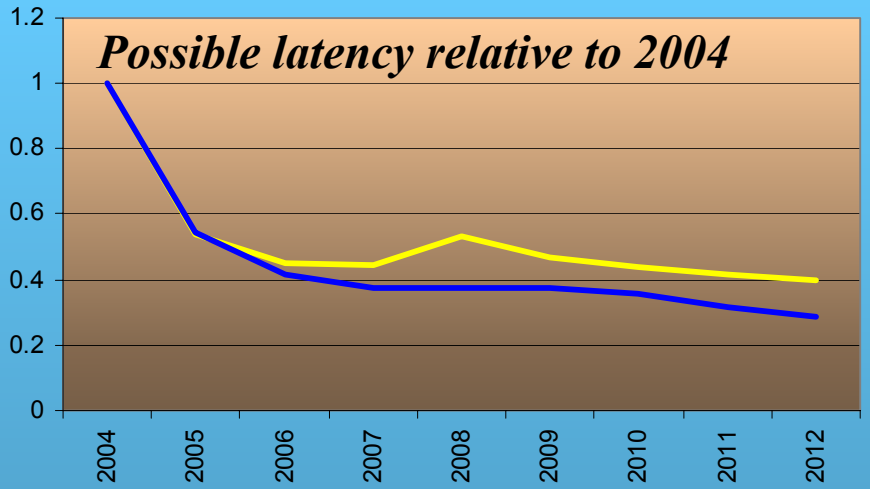
- "Faster" POD could mean:
  1. More work done within the same time frame (= bigger POD)
  2. Same work done within a shorter time frame (= shorter latency)

  IGS wants more work done *and* within a shorter time frame
- Reasons for reducing latency: ultra-rapids, ultra-rapid predictions, (near) real-time processing
  - True real-time filters are not (yet) common at Analysis Centres
  - Real-time outputs can then be produced from frequently updated predictions, made by any classical POD process. Two options:
    - short latencies within a single series of processes
    - parallel series of processes that overlap in time

Faster POD (2)

- Considering increase due to stations and GNSS only:
  - Hardware improvements can be used to reduce latency
  - Increase in POD workload and improvement of hardware are approximately linear: stable ratio between the two
  - Latencies could be reduced by about 50% in the long term





EGNOS comparison

- Essential features of EGNOS system:
  - 48 GNSS satellites
  - 60 stations
  - Precision ~few meters
  - Hardware standards consolidated < 1999 level
  - Short-latency batch POD processing
- Comparison with IGS systems lead to estimate that ~2008 hardware will allow for processing of EGNOS case with IGS-like POD systems
- See position paper for some further details

Conclusions

- An attempt was made to assess future IGS POD processing requirements against future computer capabilities
- Such estimates necessarily contain assumptions or some speculation. To compensate, conservative and progressive values have been considered.
- The expected increase due to more GNSS satellites or IGS stations can be compensated by hardware improvements
  - Some surplus in hardware improvement can reduce latency
- High-rate combination solutions for GNSS + LEO may be prohibitive for many years to come, but reduced POD processes can allow inclusion of LEO – see IGS LEO poster.
- New products or more detailed models have not been considered here, but will add to POD processing workload