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Comments on TA 11.1.1 Flight Computing (Fault-Tolerant Spaceborne Computing Technologies)

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Overview of Comments

- The NASA roadmap for space/flight computing is a significant game changer
  - …for more than NASA
  - Recommend high priority
- Gaps
  - Memory and storage
  - Trust & Security

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Game Changer like DOS → Windows

- Around 1990-1995, MS Windows started to displace MSDOS on the desktop with far-reaching results
- Reasons:
  - Windows system software enabled effective production of more sophisticated applications
  - New applications led to hardware advances in a self-reinforcing cycle
- NASA roadmap suggests a modern computing infrastructure for multi-core, accelerated computers
- Potential consequences:
  - More effective growth of low-power, embedded applications
  - Drive hardware diversity drive beyond HyperX and Maestro

In retrospect, how many of the things that run on your desktop wouldn't have developed if we were still using DOS?

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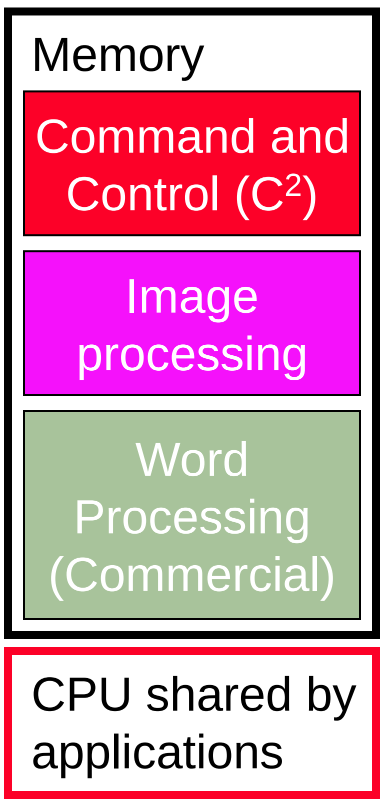
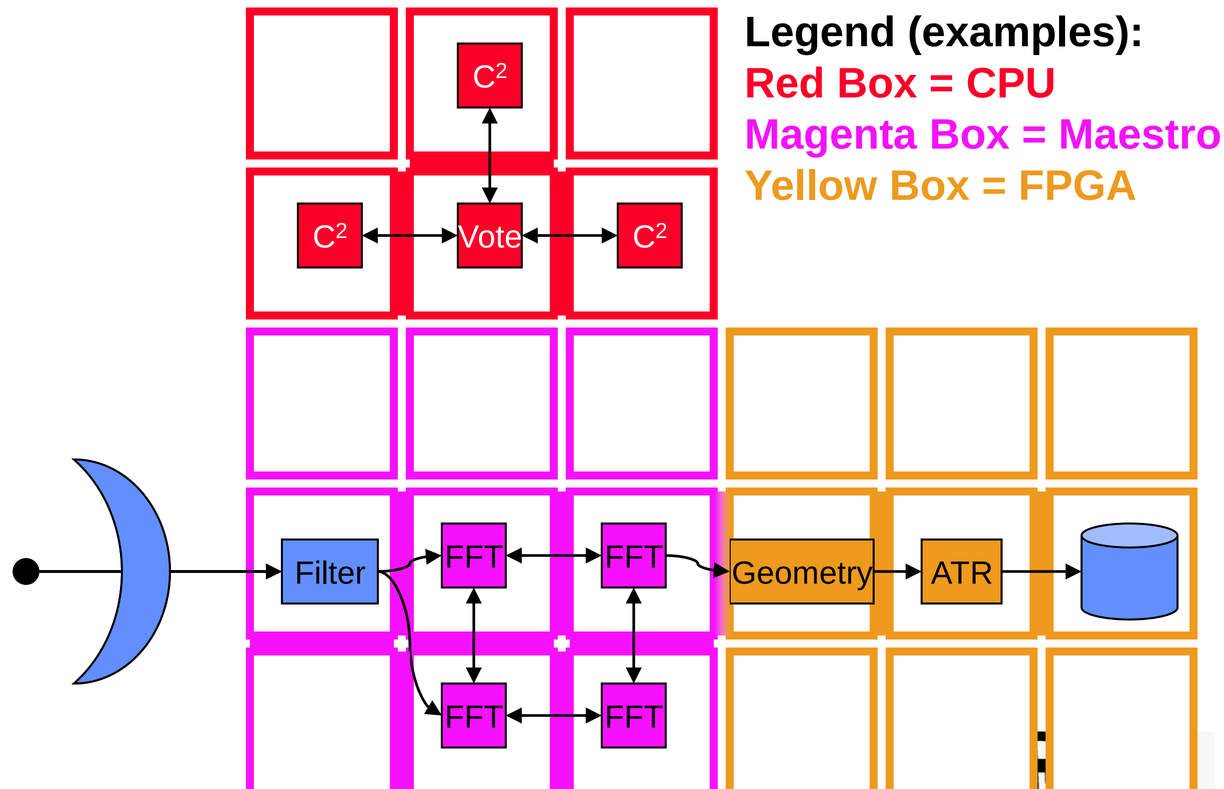
Technical Basis of Game Change

- **Current "game" puts applications into memory, sharing CPU**

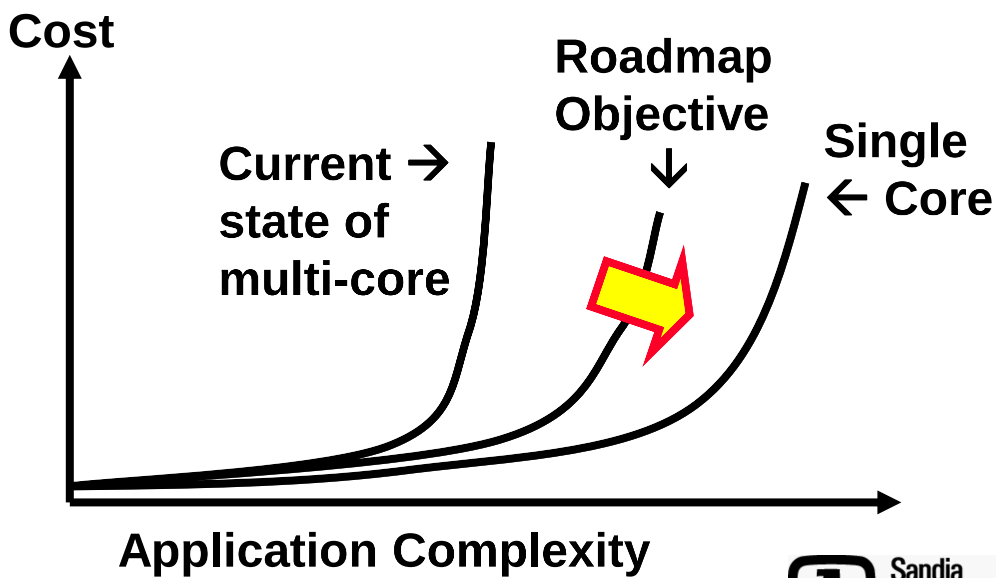


- **Changed game allocates applications to compute resources**
  - **More CPUs, optimized to task**



Challenge is to Communicate Vision

- **In panelists view, the key challenge will be communicating the objectives of this roadmap**
- **The cost of software is nonlinear with the complexity of the application, but the steepness of the curves vary**
- **NASA seeks to cut the steepness**
- **This message must be made effective for the public**



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NASA's Role?

- Status of Other Players
  - Non-Space Industry
    - Strategy 1: Run on one core at a time
    - Strategy 2: CPU-GPU
  - Other Government Agencies
    - I don't see anything nearly as sophisticated as the NASA roadmap
    - Other government agencies will share what they have
  - Industry (Primes)
    - Proprietary solutions
    - Point solutions (e. g. chip X in isolation)
- NASA activity
  - NASA will have to take a leadership role if NASA wants the vision in the roadmap implemented,
    e. g.
    - energy efficiency
    - fault management
    - verification
  - However, industry might take over from NASA
    - NASA over engineers for industry's taste, but over engineering might be OK in these cases
    - NASA give to industry, buy back next version for $1000

A. Top Technical Challenges

1. Integrate the large range of features described in the roadmap
   - To be sufficient for NASA to create reliable and fault-tolerant flight/space computing applications with reasonable development productivity
   - This type of project is unprecedented for NASA; an analogy outside NASA might be the development of PCs with Windows
   - Progress is inevitable; the question will be how much.
2. Enhancement of Fault Detection Isolation and Response (FDIR) to accommodate multi-core and accelerator chips
3. Development of rad-hard multi-core and accelerator chips is essential
   - These projects are challenging, but they have precedent

B. Technology Gaps

- **Memory and Storage**
  - **The envisioned processors will need larger and faster memory and storage than will be possible with DRAM, SRAM, and Flash**
  - **New nanotechnologies on the way, but need work to meet spaceflight requirements**
- **Trust and Security**
  - **Trust and security are growing issues**
    - **E. g. trusted components**
    - **Keep hackers from taking over your satellite**

C. High Priority Areas

- Top items in this reviewer's opinion:
  - FDIR for COTS multi-core μPs and other architectures
  - Four single-core chips can be architected to avoid faults in one chip killing the others. However, industry did not design quad core chips to have this property. It is possible COTS multi-core chips will not meet space reliability requirements

D. Alignment with Expertise

- This roadmap would indicate a combination of
  - NASA
  - NASA FFRDC (JPL)
  - Universities
  - Companies

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E. Is it Competitively Placed?

- [Panelist may not understand this question.]
- The space/flight computing item 11.1.1 is described in the roadmap without indication to who does the work
- Panelist believes the work would be done effectively by
  - NASA and FFRDC non-competitively and
  - universities and industry competitively
- Furthermore, panelist thinks industry would adopt some of the NASA technologies for non-NASA applications. NASA would end up with free upgrades and support. Examples:
  - medical computers
  - nuclear power plant controllers
  - automotive electronics

F. Game Changing Technology – Yes

- **The space/flight computing would be game changing for NASA, other aerospace, other Government, and potentially industry**
- **We know how to harness the benefits of "Moore's Law" effectively only for single-core CPUs**
- **The space/flight computing roadmap would "unlock" Moore's Law for scalable, embedded, real-time, high reliability applications, notably space**

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G. Space Computing Near Tipping Point?

- The amount of computing in space is ready a big leap forward
  - The community has been lagging in benefitting from Moore's Law by the inability to use multi-core
  - If we figure out how to use multi-core, may see a brief period of unusual progress as we eat away at a backlog of Moore's Law advances

H. Schedule

- The schedule per table 1 is seems plausible to this reviewer
  - However, the 2013-2016 milestones would start to lose reasonableness if there were budget and contracting delays
  - The 2025 and 2030 could probably be pulled in a bit
    - 2030 is 19 years out!

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I. Payoff, Risk, Barriers, and Success

- **NASA's space computing roadmap is inevitable**
  - **It is unimaginable that 10, 20, 50, 100 years would go by and we would fail to figure out how to program multi-core processors**
- **The success criteria is <u>how soon</u> do we see effective use of multi-core and <u>how much</u> can the engineering and software development productivity be improved?**