RAS by the Yard

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The architectural flexibility that permits a customer to select the appropriate amount of fault tolerance

Cost-Benefit Analysis

- Improving RAS has many benefits
  - ...for a cost
- Given a fixed budget
  - Can trade RAS for performance
  - Would like the flexibility to select the optimal RAS/performance combination

As an example, consider a 1 PetaFLOPS supercomputer in the 2010 time frame...

System Balance Parameters

- To maximize application performance
  - In this case, scientific supercomputing applications

System Balance Parameter	*Ratio*	*Value for a 1 PetaFLOPS System*
Peak compute performance	1 PetaFLOPS (fixed)	
Memory size	0.5 Bytes/FLOPS	0.5 PetaBytes total
Memory bandwidth	0.5 Bytes/FLOPS	0.5 PetaBytes/sec total
Bisection bandwidth	0.12 Bytes/FLOPS	0.12 PetaBytes/sec total
I/O Bandwidth	0.002 Bytes/FLOPS	2 TeraBytes/sec total
Disk Bandwidth	0.001 Bytes/FLOPS	1 TeraBytes/sec total
Disk Storage	50 Bytes/FLOPS	50 PetaBytes total

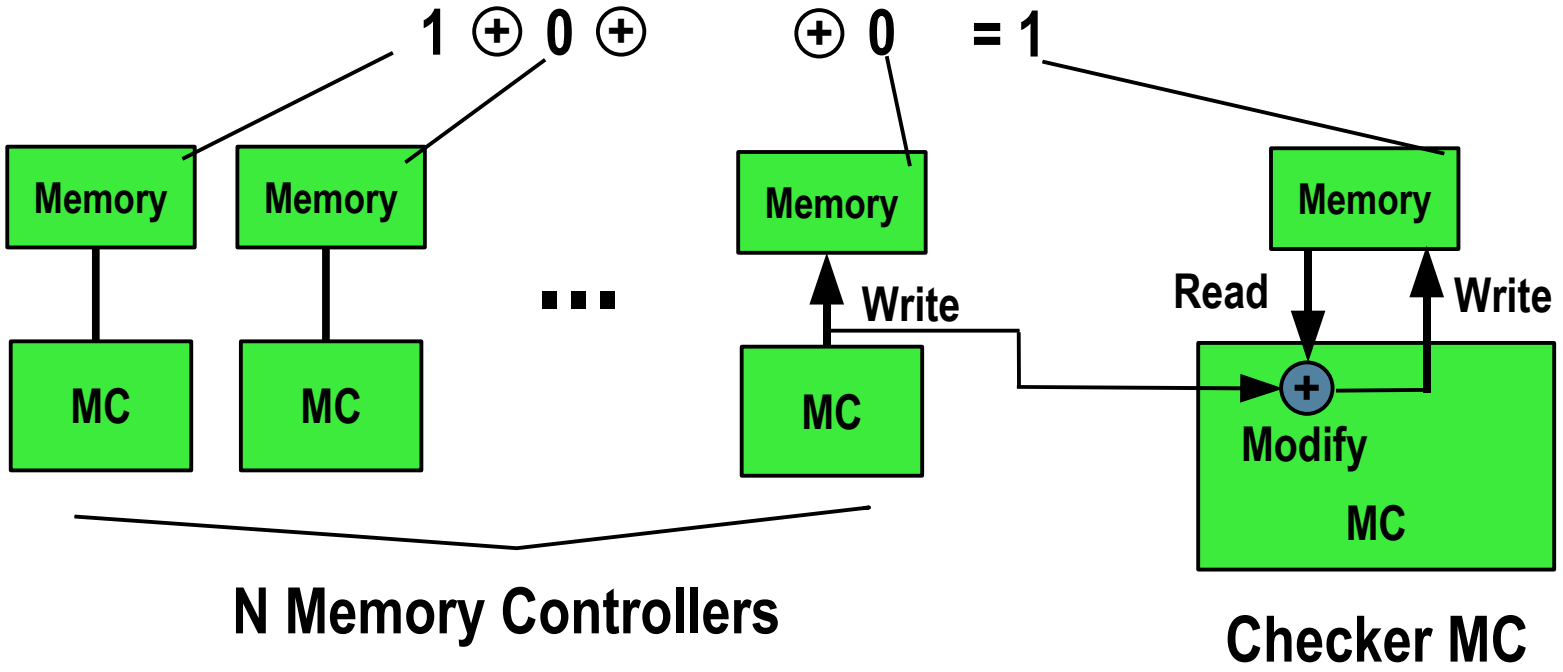
Subsystem Costs

Subsystem	*Definition*	*Cost in %*	*Cost Driver*
Processor	Microprocessors; cache; CPU board hardware	39%	Peak Performance
Memory	DIMMs; memory controllers	28%	Memory Size
System Interconnect	Controllers and switches; cables and connectors	14%	Bisection Bandwidth
Storage and I/O	Disks; disk and I/O controllers	19%	Disk Bandwidth

Now consider RAS improvements...

Fifth Memory Channel

- Memory RAID (N+1) approach to improve memory system reliability
  - In this example, application availability increase of 11% (double MTBF) for 25% more memory



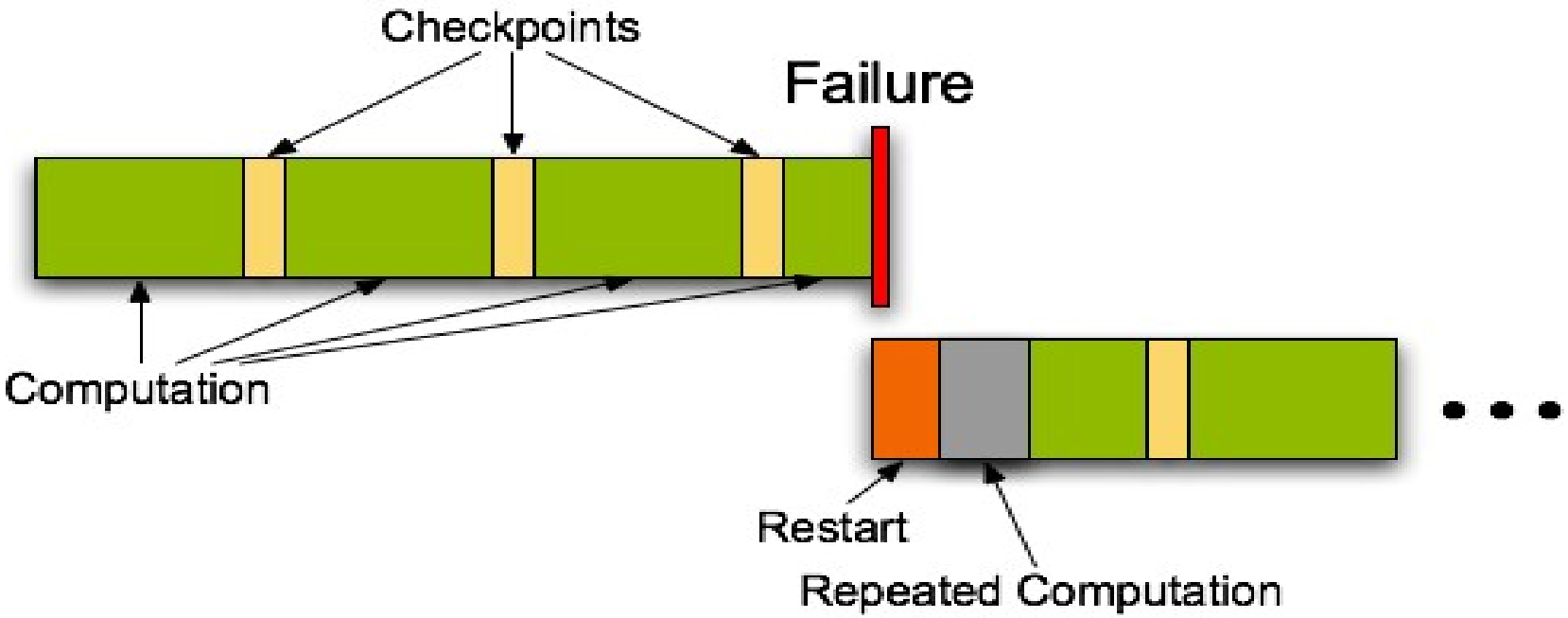
Rebalanced System Cost

- In this example, adding 25% more memory increases system cost by 7% but increases availability by 11%
  - > Readjust subsystems to maintain system balance with a fixed budget

Subsystem	*System Parameters*	*Original Cost*	*Cost with 5th Memory Channel*	*Rebalanced Cost*	*New System Parameters*
Processor	**1** PetaFLOPS	**39%**	**39%**	**36%**	**0.93** PetaFLOPS
Memory	**0.5** PetaBytes	**28%**	**35%**	**33%**	**0.47** PetaBytes (**0.59** PB Total)
System Inter-connect	0.12 PB/sec	14%	14%	13%	0.11 PB/sec
Storage and I/O	2 TB/sec I/O 1 TB/sec Disk	19%	19%	18%	1.86 TB/sec I/O 0.93 TB/sec Disk
		100%	**107%**	**100%**	

Checkpoints

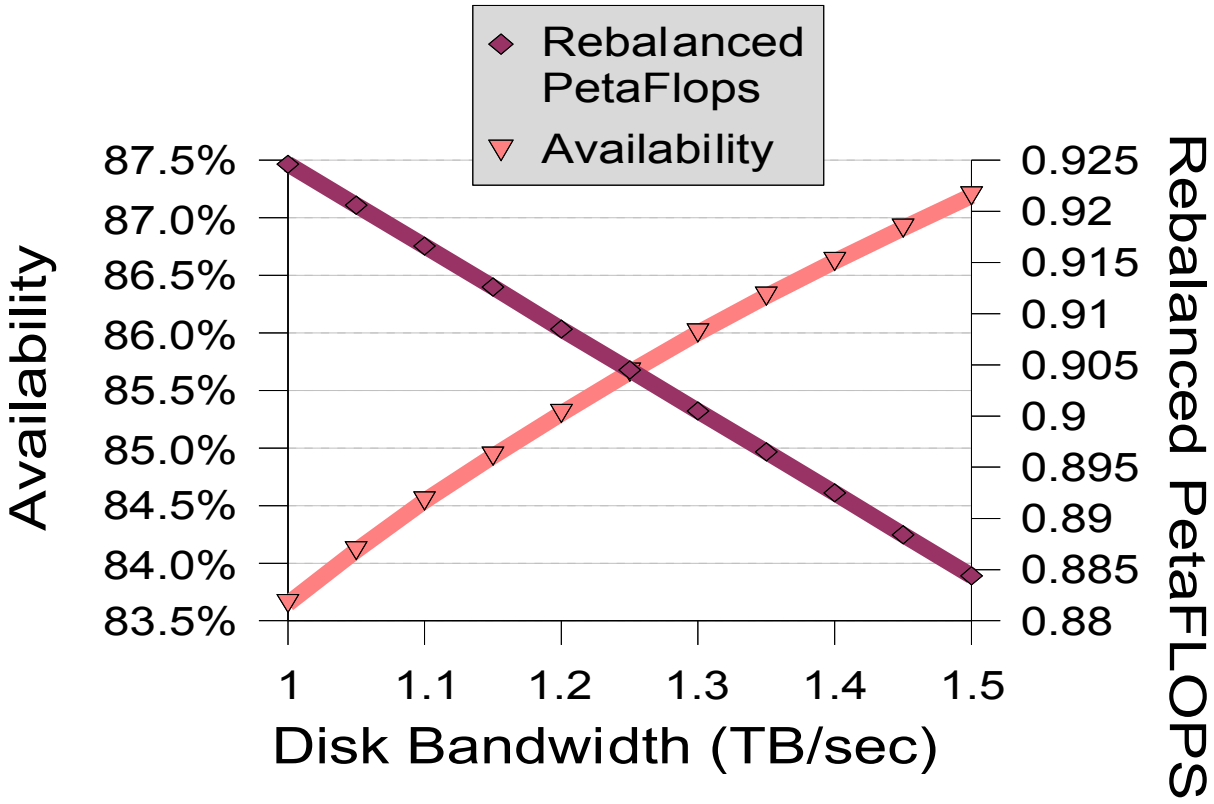
- Contain all information necessary to restart computation
- Used to recover from failures, for debugging, and to replay application



Green areas are application availability

RAS by the Yard

- With checkpoints and a 5th memory channel
  - > Increasing disk bandwidth improves checkpoint speed and application availability but costs performance

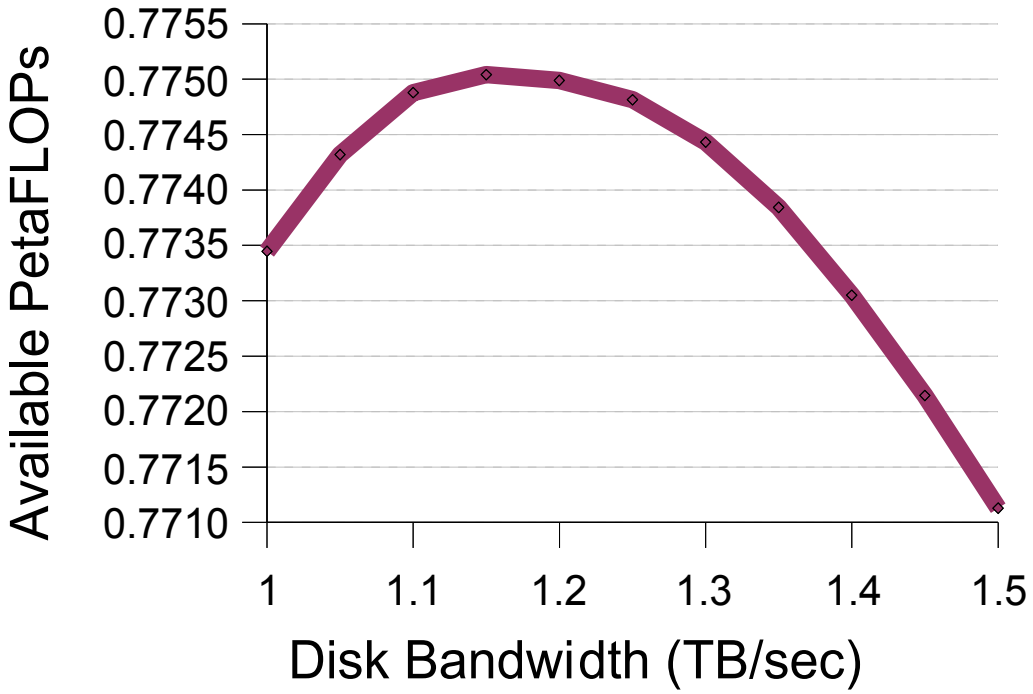


Available PetaFLOPS Definition

- A simple performability metric that combines availability and performance
  - = application availability x peak PetaFLOPS
- Could be improved by
  - Using a benchmark measure instead of peak PetaFLOPS
  - Considering non-linear productivity benefits of improved RAS

Available PetaFLOPS Example

- With checkpoints and a 5th memory channel
  - > Optimal combination of availability and performance occurs at disk bandwidth of 1.15 TB/Sec



Summary

- RAS by the yard provides options for customers
- Flexibility must be included in system architecture planning to provide choices, preferably a continuum
- Can use performability metric to select optimal system for a fixed budget
  - Need research on non-linear productivity benefits

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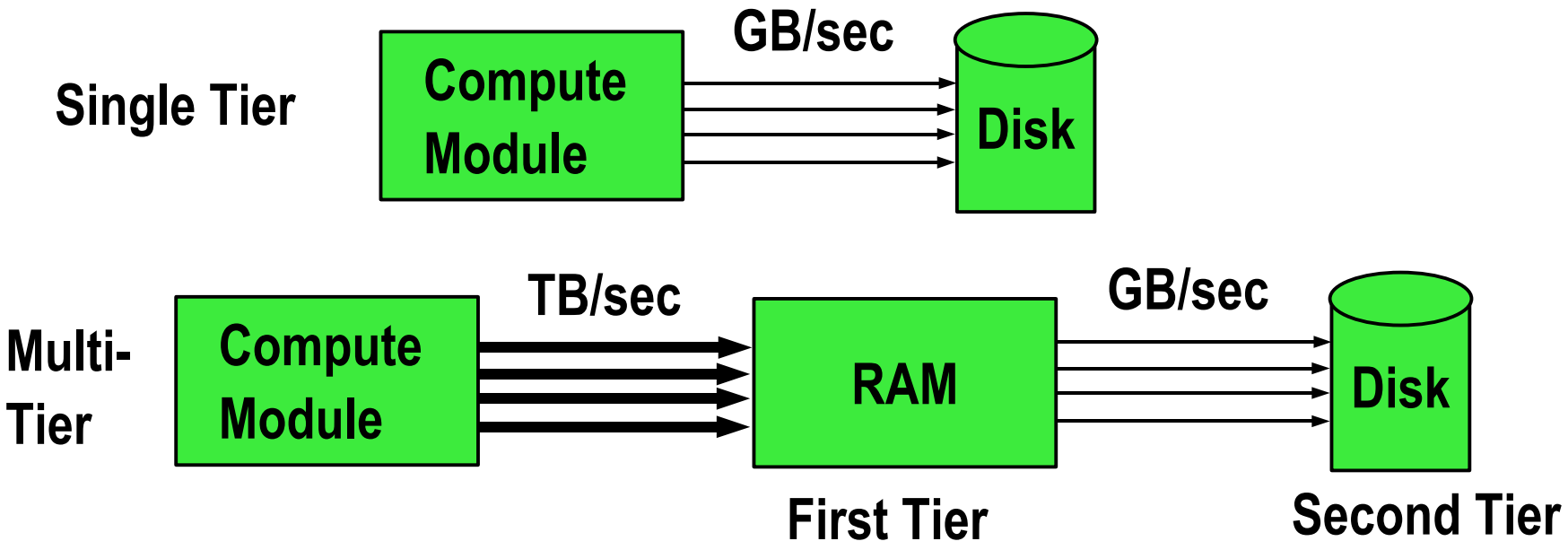
Multi-Tiered Checkpoint Storage – RAM Checkpoints

- Checkpoint first stored quickly in RAM, then moved to disk as background task



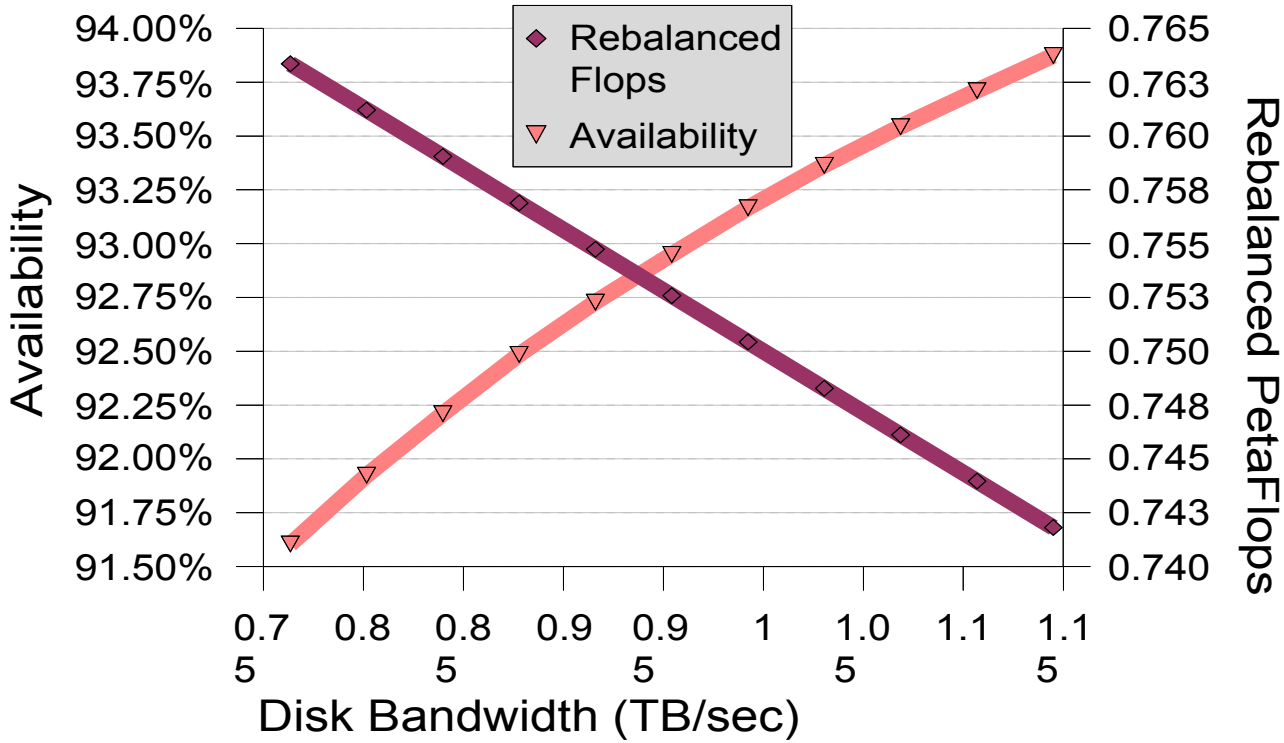
RAM Checkpoint Rebalanced Cost

- Adding 100% more memory increases system cost by 28% but increases application availability by 17% (75% to 92%)

Subsystem	*System Parameters*	*Original Cost*	*Cost with 5th Memory Channel*	*Rebalanced Cost*	*New System Parameters*
Processor	**1** PetaFLOPS	**39%**	**39%**	**30%**	**0.77** PetaFLOPS
Memory	**0.5** PetaBytes	**28%**	**56%**	**45%**	**0.39** PetaBytes (**0.78** PB Total)
System Inter-connect	0.12 PB/sec	14%	14%	10%	0.09 PB/sec
Storage and I/O	2 TB/sec I/O 1 TB/sec Disk	19%	19%	15%	1.55 TB/sec I/O 0.77 TB/sec Disk
		100%	**128%**	**100%**	

RAS by the Yard

- With RAM checkpoints (no 5th memory channel)
  - > Significantly better application availability



Available PetaFLOPS Example

- With RAM checkpoints (no 5th memory channel)
  - > Optimum at disk bandwidth of 0.89 TB/Sec
  - > 5th memory channel has higher Available PetaFLOPS