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Designing and implementing mission-critical systems

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BC, DT, HA and DR (1)

- Business continuity:
  - It's not just the systems – it's everything!
- Disaster tolerance:
  - Continue operations while surviving major site outages without loss of data
- High availability:
  - Continue operations while surviving equipment and software failures at a site without loss of data

BC, DT, HA and DR (2)

- Disaster recovery:
  - The process of restarting sufficient operations to run the business after an serious outage, typically from another location

- Budget and Schedule:
  - They have to be appropriate for the problems we're trying to deal with. Don't set them first!

Problem solving concepts - TRIZ

	Before	Now	After
Environment			
System			
Component			

See www.triz.co.uk for a lot more information!

Design decisions

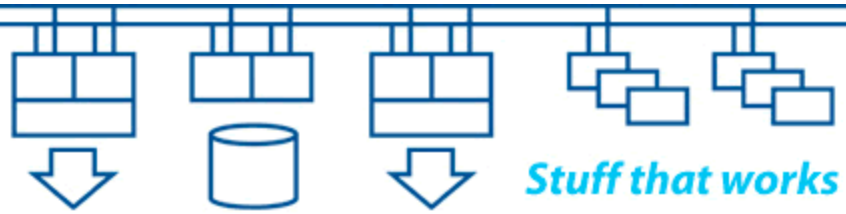
- Big decisions which have long-term implications and constraints
- Small decisions which seem big at the time
- There will be requirements and constraints you don't yet understand or know about
- Need to design in the ability to make changes
- Establish a meaningful naming convention

Risk

Risk is a fact of life. We have to deal with it as best we can – or at least well enough for the circumstances we find ourselves in.

Think about both project management and technical design as part of systems engineering, then apply techniques from other engineering disciplines to help us analyse the situation and guide our thinking.

Disaster-tolerant systems aim to minimise the risk of loss of service and loss of data as much as possible.



The risk continuum

- What is the probability of a situation occurring ?
- What is the impact if that situation occurs ?
- What are the long-term consequences ?

- Most projects handle medium risk well enough
- Many projects over-specify to cater for what are in fact low risk issues
- Some projects under-specify and fail to cater for what are in fact high risk issues

Mission Critical systems

Mission critical systems need to be able to:

- Survive failures (resilience and failover)
- Survive changes (adapt and evolve)
- Survive people (simplify and automate)
- Never corrupt or lose critical data (data integrity)

- Requirements never remain static over an extended period of time, so we need to be able to make changes during the operational lifetime of the system
- Circumstances change, so we often need to be able to extend the operational lifetime and scope of a system

Do we really need 100% uptime?

- Safety-critical systems (especially real-time monitoring and control systems such as air traffic control) require exceedingly high levels of availability. They also have to be fail-safe in order not to endanger lives.

- True 24x365 mission-critical systems are fairly rare. With these there is no "downtime window" to take backups, fix faults or to make changes. So, whatever you do has to be done "live" – and very carefully!

The systems "flight envelope"

- What does the business require the systems to do ?
- What are the consequences if the systems fail ?
- What happens if you push beyond the limits ?
- How far from the edge are you ?
- How do you know ?
- What can we measure ?
- What comparisons can we make ?
- What evidence can we look at ?

"Survivability test" (1)

Cause of Outage:	Planned (Maintenance)	Unplanned (Failure)
Hardware	?	?
Operating System	?	?
Network Layer	?	?
Layered Products	?	?
Application Software	?	?
Application Data	?	?
Environment	?	?
People	?	?

"Survivability test" (2)

- How long have we got ?
- How much data can we afford to lose ?

- How can we model the whole system ?
- How can we predict the overall availability ?

- The closer you get to 100% uptime the more expensive a satisfactory solution will become

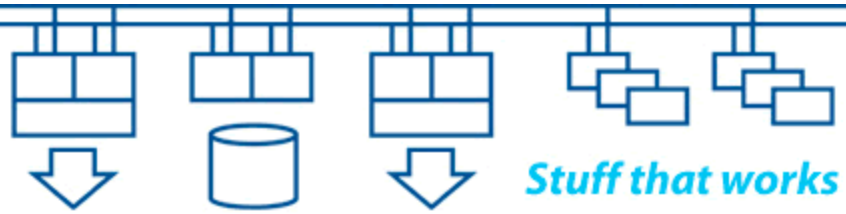
RPO and RTO

RPO = Recovery Point Objective

- How much data can we tolerate losing ?
- How quickly do we need to react to a failure ?

RTO = Recovery Time Objective

- What level of service outage can we tolerate ?
- How quickly do we need to recover ?
- How quickly do we need to be ready to deal with a subsequent failure ?



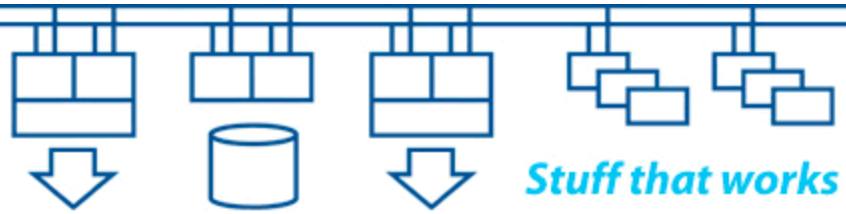
Availability and performance (1)

Availability:

- Probability of system being available for use at a given instant in time within the 'operational window'
- Function of both MTBF (reliability) and MTTR (repair time)

Performance:

- Performance issues are often the cause of transient system failures and disruption
- The systems have to have sufficient capacity and performance to deal with the workload in an acceptable period of time under normal, failure and recovery conditions



Availability and performance (2)

- Why is understanding performance so important in mission-critical systems ?

- How does performance affect availability ?

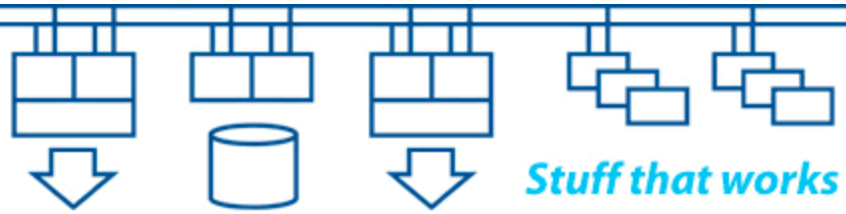
- What can we do to test a system before it goes into production ?
- What can we do to test changes to a system before we implement them ?
- What can we do to monitor a system once it's in production ?

Throughput and response times

- Bandwidth – determines throughput
  - It's not just "speed", it's throughput in terms of "units of stuff per second"
- Latency – determines response time
  - Determines how much "stuff" is in transit through the system at any given instant
  - "Stuff in transit" is the data at risk if there is a failure
- Jitter ("div latency" or variation of latency with time) – determines predictability of response
  - Understanding jitter is important for establishing timeout values
  - Latency fluctuations can cause system failures under peak load

Designing for performance

- Size systems to cope with peaks in workload
- Minimise "wait states" (caches, parallelism)
  - Don't make it go faster, stop it going slower
- Minimise contention for resources and data structures
- Understand the need for synchronisation and serialisation of access to data structures
- Maximise "User Mode", minimise the other modes:
  - The fastest IO is the IO you don't do
  - The fastest code is the code you don't execute



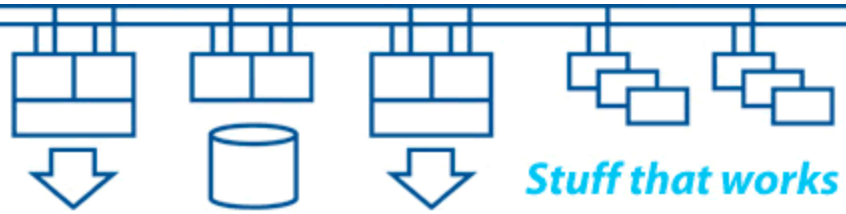
Parallelism and scalability

- Understand how the applications could break down into parallel streams of execution:
  - Some will be capable of being split into many small elements with little interaction between the parallel streams of execution
  - Some will require very high interconnectivity between the parallel streams of execution
  - Some will require high-throughput single-stream processing

- Understand scalability – do as much as possible once only, do little as possible every time

Designing for availability

- Which parts of the system are mission-critical ?
- Which parts of the system are safety-critical ?
- What kind of failure do we prefer ?
- What state transitions occur during both failure and recovery ?
- What happens if there's another failure part way through a state transition during a failure ?
- How can we recover from a failure without data loss or data corruption ?
- How will you test your failure and recovery scenarios ?
- How can you make changes while it's working ?



Multi-site issues

- Naming conventions
- Quorum and voting schemes
- Data replication schemes
- Effects of distance on network and storage protocols
- Symmetric or asymmetric operation – how good is your "crystal ball" ?
- Centralised (and replicated) monitoring and alerting
- Remote access for management and operation
- Avoid automation of decision making

State transitions (1)

- Nothing happens instantaneously - there is always a "state transition"

- How long do state transitions last for ?
- What can we do while a state transition is in progress ?
- Can we ensure that there are no timing windows or other flaws in the design ?

- What possible states can a pair of machines be in ?

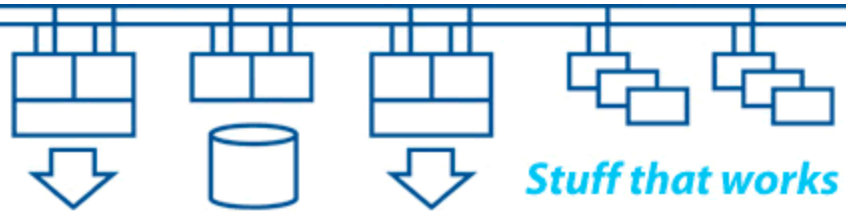
- How can we test it ?

State transitions (2)

A	B
Off to Master	Off
Master	Off to Standby
Master to Off	Standby to Master
Master to Off	Off to Master
Master to Standby	Standby to Master
Master to Hung	Standby to Confused
…	

- We need to demonstrate that service will continue with minimal disruption during failure and recovery
- We need to regularly rehearse and test our procedures and plans to ensure that we stay current

- We need to test scalability as well as functionality
- We need to test every aspect of the system and surrounding infrastructure under normal, failure and recovery conditions
- How will we generate a realistic load for testing ?
- How will we instrument the system and infrastructure ?



Risk identification and assessment

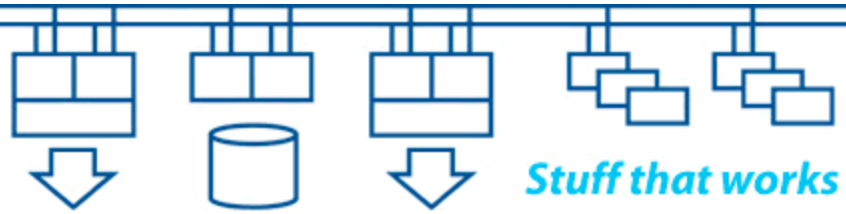
- How can we start to identify what the risks might be ?
- How can we look for single points of failure ?
- How can we look for modes of failure ?
- Can we identify specific scenarios of interest ?
- Can we test all the conditions ?
- What happens to our data ?

Analysis Techniques

There are many techniques which have evolved over the years and there are tools to help you apply them.

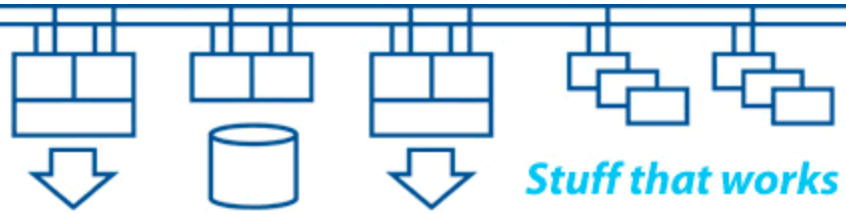
- Reliability Block Diagrams (RBD)
- Fault Tree Analysis (FTA)
- Failure Modes, Effects and Criticality Analysis (FMECA)

These (and many other) techniques can be applied with software tools available from a number of vendors.



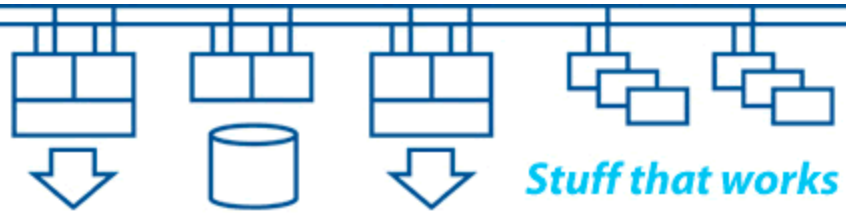
Measuring system behaviour

- How do we instrument the system ?
  - Application level
  - Operating system level
  - Data storage level
  - Network infrastructure
- Time synchronisation
- How do we generate a typical workload ?
- How do we generate representative data sets ?



Controlling change

- Physical environment (power, cooling, etc.)
- Hardware (revision levels, labelling, etc.)
- Firmware versions and updates
- Operating system updates
- Network infrastructure and configurations
- Storage infrastructure and configurations
- Database versions and configurations
- Application software versions and configurations
- Interoperability and interactions
- Upgrade and backout actions
- Data conversions and one-way processes

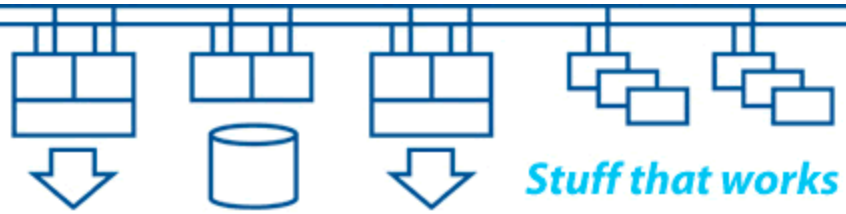


Failure and recovery

- Mission-critical systems hardly ever fail, so we need the people responsible for its operation to have a good understanding and 'feel' for the way it works

- We need to find out how the system behaves when it starts to fail
- We need to know the 'warning signs' of incipient failure
- We need to know how to return the system to its normal operational state without data loss or data corruption

- We must have a representative offline environment

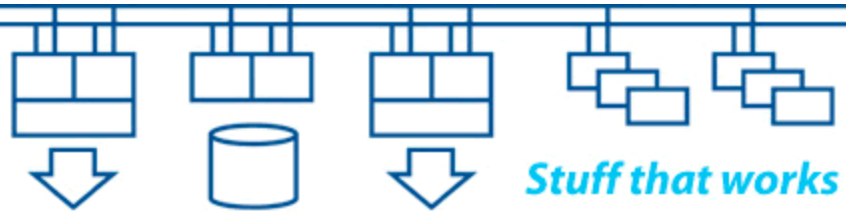


Finding and fixing problems

- Where can we do the testing ?
  - Production environment
  - Pre-production Test environment
  - Pre-delivery Test environment

- How might a problem show up – and when ?
- How can we find a problem, eg: data corruption ?
- Can we recreate a problem in a test environment ?

- Continual monitoring and event logging is essential
- Knowledge of the whole system is essential

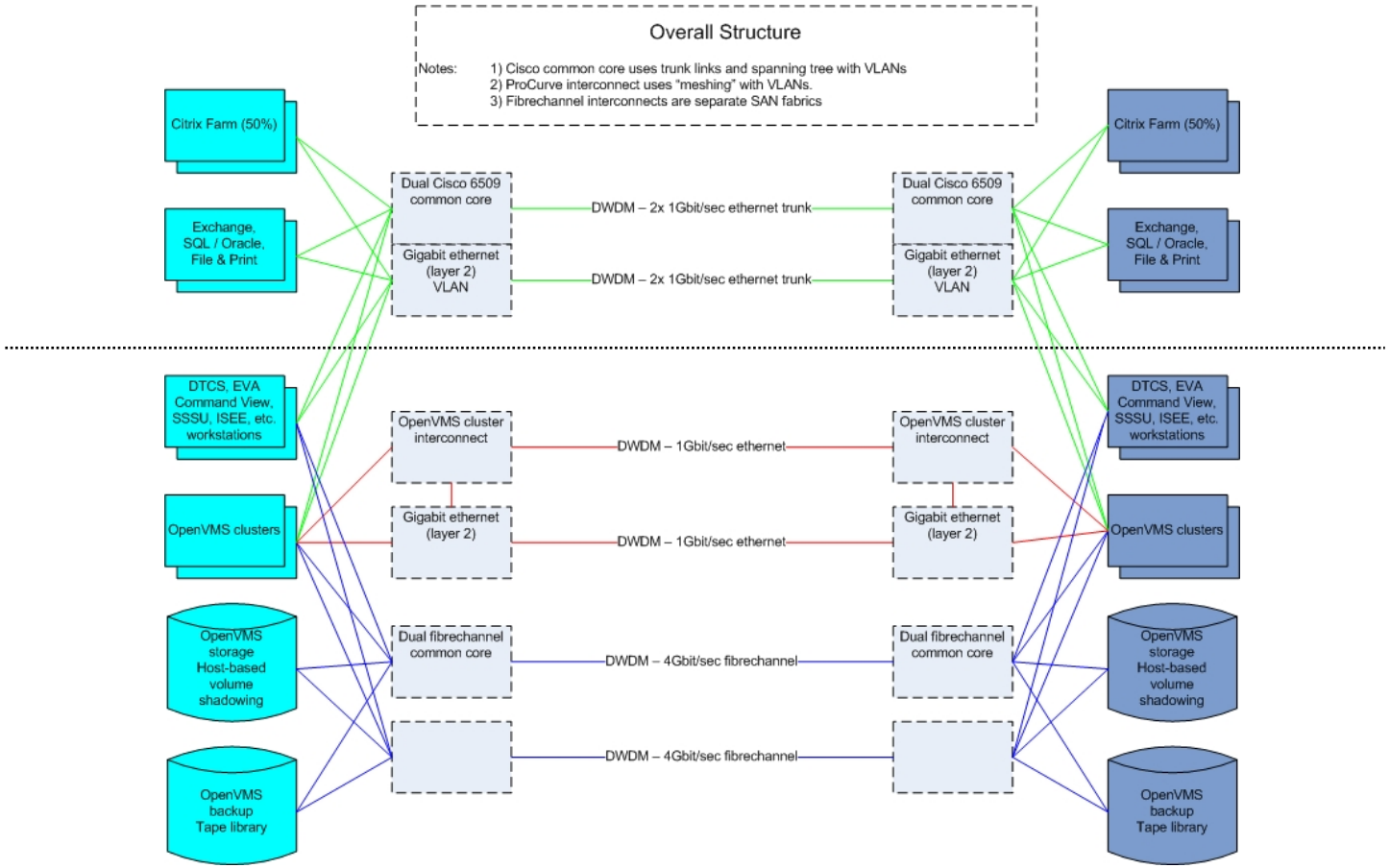


Example - NHSBT "Pulse"

An overview of how the new NHSBT Pulse systems fit into the NHSBT infrastructure.

We have Production, Archive and Test environments with a shared common infrastructure, all of which is separated from the rest of the existing infrastructure.

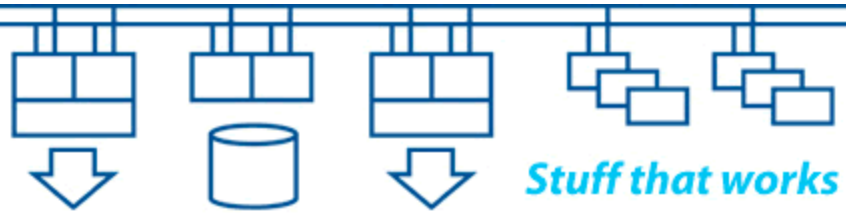
Overall structure



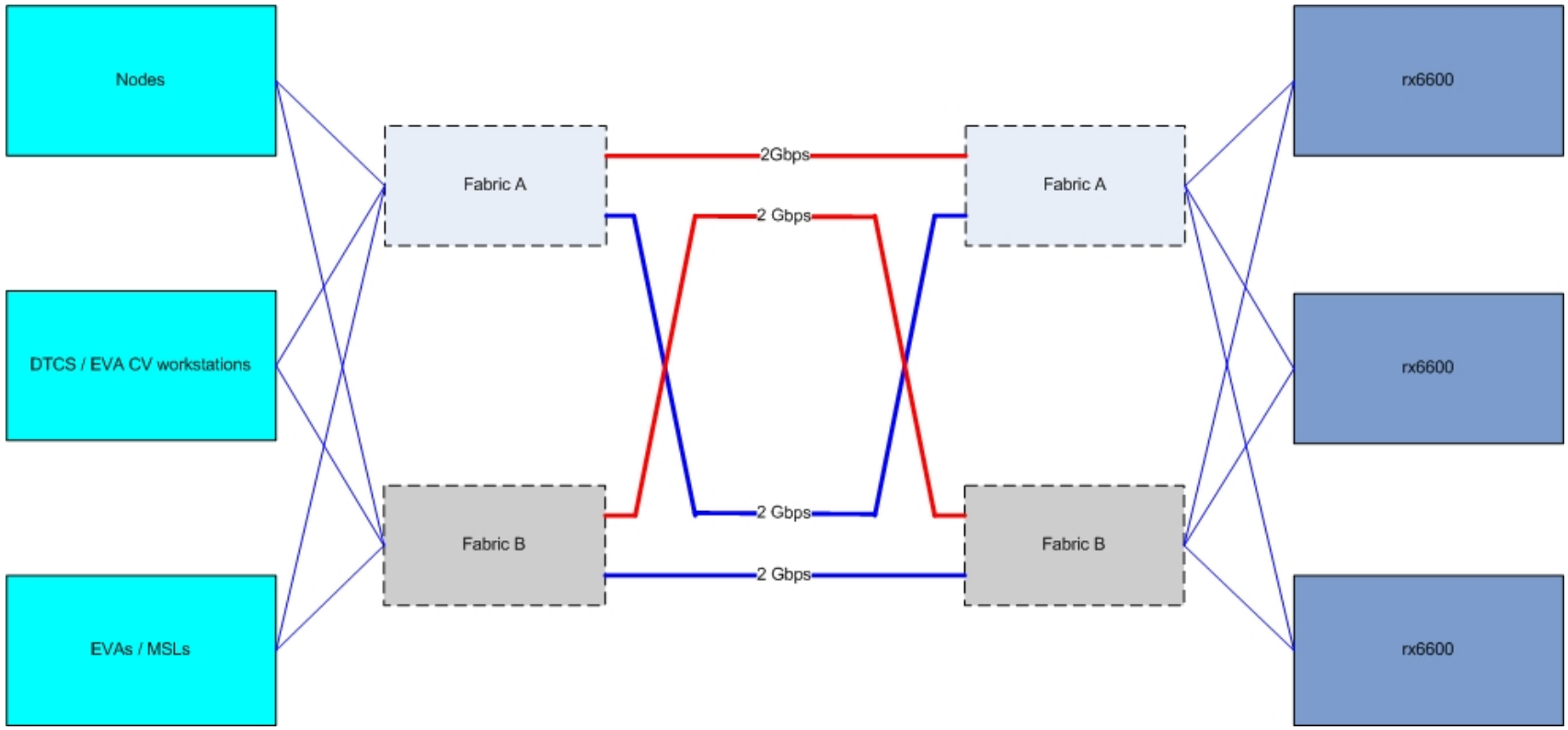
Functional layout

The systems are split up into:

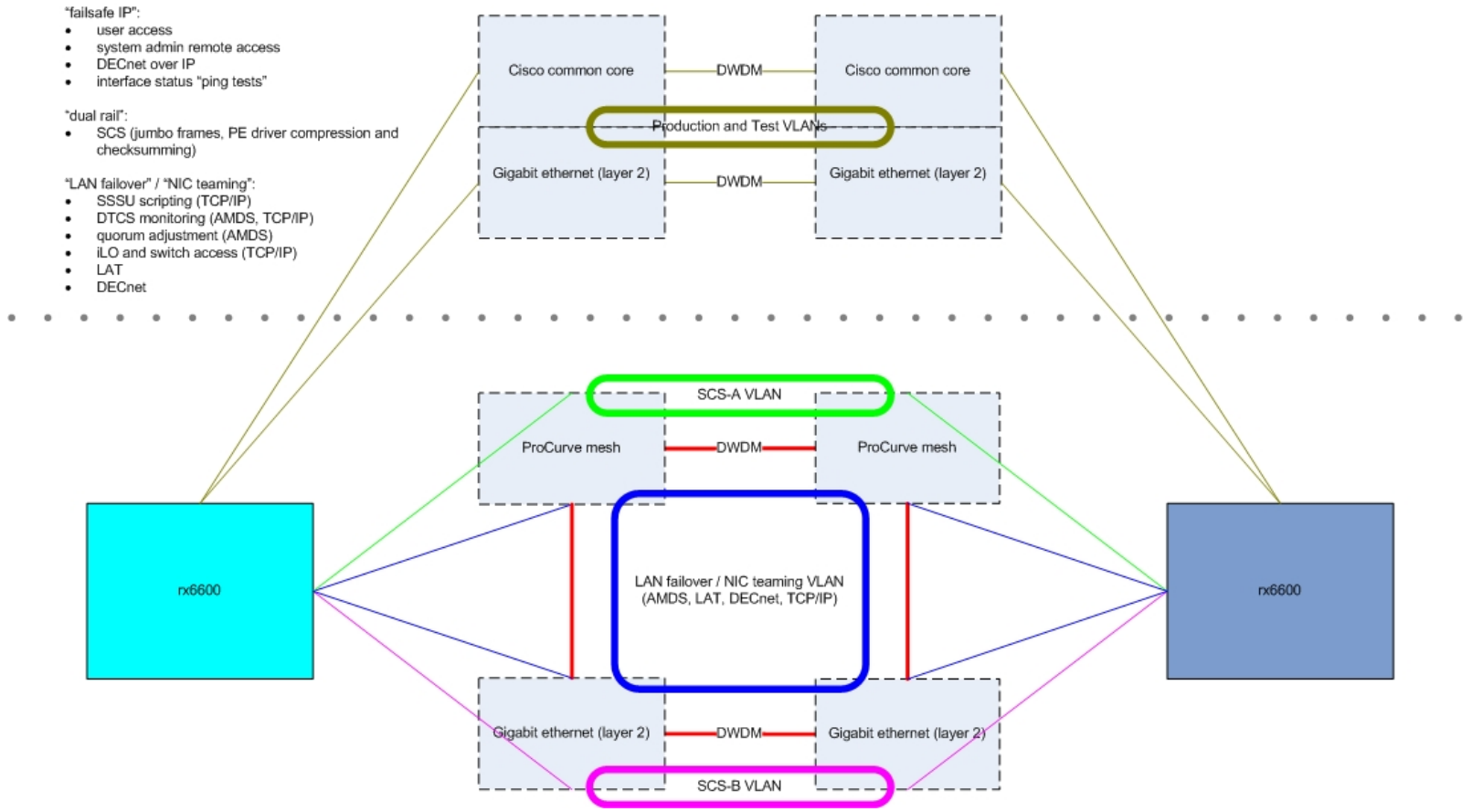
- Common infrastructure (SAN fabrics, private network interconnects etc.)
- Production environment (a split-site cluster with host-based volume shadowed storage)
- Test environment (a split-site cluster on a smaller scale)
- Archive environment (a single node at Site A)
- Duplicated monitoring and reporting facilities
- External connectivity for users



Common SAN fabric infrastructure

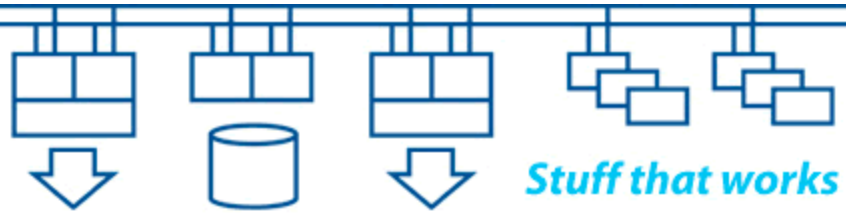


Common data network infrastructure



Multi-site clustering

- Multi-site OpenVMS clusters give us "shared everything" access to data with protection from loss or corruption, even in the event of site failure
- Host-based volume shadowing (HBVS) ensures that data is consistent across all members of the shadow sets.
- The quorum scheme lets Site A continue if Site B fails and protects us from data corruption due to a partitioned cluster
- DTCS monitors the systems and (most important of all) controls the formation of storage shadow sets when the systems boot and when nodes rejoin the cluster



DTCS – monitoring and control

- DTCS is a set of HP and 3rd party products with installation, configuration and support services
- Remote console access, management and console output logging
- Integrated monitoring and quorum adjustment
- Rule based monitoring of individual systems / nodes
- Rule based SNMP polling of equipment
- Rule based TCP/IP "ping reachability" polling
- GUI and e-mail based alerting
- Scripting of failover and recovery actions across all systems / nodes and storage subsystems

Success factors

- Small team of committed people
- Clear objectives
- Built ‘proof of concept’ data migration system first
- Built system ‘on paper’, discussed it extensively and resolved potential technical problems prior to purchasing equipment and building system platform
- Project management and planning
- Leadership and collaborative working
- Trust between team members
- Sufficient flexibility to cope with issues as they arise

Summary

- The art is to select elements that work well together and which provide the bulk of what you need with minimal additional work
- Establish the minimum requirements that have to be met – and do it as well as possible
- Availability and performance have to be designed in to the application
- Monitoring and automation are key components
- Understand the typical behaviour of your systems and be aware of changes

Key issues

- You can't buy high-availability off the shelf
- Do the minimum you have to do and get it right
- Design for change on-the-fly with no loss of service
- Protect the data - ensure correctness and consistency
- Monitoring, information and automation
- Documentation and configuration control
- Testing and continual training

- Procurement – do enough work up front
- Build "proof of concept" early on
- Project management
- Leadership and collaborative working

Thank you for your participation

Discussion!