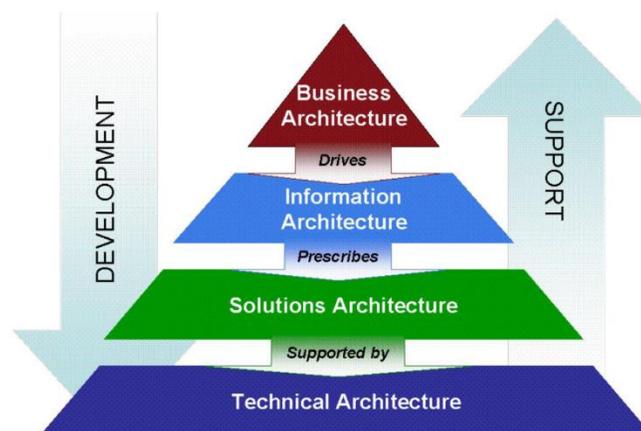




Enterprise Architecture Technical Brief

End-User Displays

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Enterprise Architecture End-User Displays

Contents

End-User Display Recommendations 3

Recommendation Supporting Information 6

 Maximizing Your Multi-Monitor Setup. 6

 Productivity and Multi-Screen Computer Displays. 6

 How Multiple Monitors Affect Wellbeing. 8

 Increase Workplace Productivity through Intelligent Display Features and Design. 9

 Top 5: Reasons to use a widescreen monitor. 10

 Ultrawide vs Dual Monitors: Which Are Better for Productivity? 10

 The Benefits of Using Windows 10 on a 34-inch Ultrawide Monitor. 11

 Using the Multi-Display Teaching System to Lower Cognitive Load. 12

 Case Study: Nationwide Insurance – Employees Enjoy Rich and Vibrant Colors with Samsung LED Monitors. 12

 With Similar Visual Angles, Larger Displays Improve Spatial Performance by Carnegie Mellon University's School of Design. 13

 A Survey of Large High-Resolution Display Technologies, Techniques, and Applications by University of California, Davis and Pacific Northwest National Laboratory. 13

 Effect of Display Size on Users' Search Performance by the University of Stuttgart, Germany in April 2015. 14

 Increased Display Size and Resolution Improve Task Performance in Information-Rich Virtual Environments. 14

 Improving Employee Productivity with Dual Monitors. 15

 When One Isn't Enough: An Analysis of Virtual Desktop Usage Strategies and Their Implications for Design by Stanford University Computer Science Department. 15

 Washington State Office of Financial Management – Information Technology Upgrade Policy Review. 15



End-User Display Recommendations

1. Display Size Recommendation:

- a. VITA recommends transitioning from small (17"/19"/21") sized displays to current display sizes of 24" to 37" at 16:9/10:9 ratio's that meet today's task and information worker requirements requiring more display workspace.
 - i. All areas where displays are currently located or will be located should have at least a 24" display.
 - ii. Most areas where displays are currently located or will be located will benefit from a 27" display.
 - iii. Some areas where displays are currently located or will be located will benefit from a large, ultrawide 37" display, such as Accounting, Graphics, GIS, and Visio/AutoCAD users to name a few.

2. Multi-Display Recommendation:

- a. VITA recommends increasing display space to enhance employee productivity, which is generally accomplished by implementing dual/multiple displays at workspaces.
 - i. Most areas where displays are currently located or will be located and have video cards supporting larger display resolutions will benefit from having dual, 24" to 37" displays.
 - ii. Some areas where displays are currently located or will be located and have video cards supporting larger display resolutions will benefit from having two or more ultrawide 37" displays such as Accounting, Graphics, GIS, and Visio engineering to name a few.
 - iii. Some areas where displays are currently located or will be located and have video cards supporting larger display resolutions will benefit from having more than two 24" to 37" displays.
 - iv. An exception to the multi-display recommendation is when the display is at or near 37" (34"-40"), because the amount of



Enterprise Architecture End-User Displays

display workspace becomes equivalent to a dual-display configuration.

Note: VITA does not recommend using two/three/four small displays (17"/19"/21") as a method of increasing display space.

3. Display Obsolescence:

- a. VITA recommends a shortened display technology refresh cycle than previously lengthy display refresh cycles, which were upwards of a decade. Some reasons to refresh displays sooner include technology enhancements such as:
 - i. Newer aspect-ratio standards such as the now venerable 16:9 and 10:9 as compared to the previous longstanding 4:3.
 - ii. More energy savings.
 - iii. LCD displays using LED technology provide better backlighting. ¹
 - iv. Newer audio/video connection ports such as High Definition Multimedia Interface (HDMI).
 1. HDMI v1.2 up to 1080p resolution.
 2. HDMI v1.3 up to 1600p resolution.
 3. HDMI v1.4 up to 4K resolution, but only at 24fps and 8-bit color (commonly 120Hz at 1080p).
 4. HDMI v2.0 (10-bit or 12-bit color) up to 4K resolution.
 5. DisplayPort v1.2 and newer up to 4K resolution.
 - a. DisplayPort connections are the best connections for an audio/video signal and can transmit 144Hz up to 4K. ²
 - v. Latest generation device ports such as USB v3.0.
 - vi. Touchscreen capability, etc.

¹ Here's How to Buy a New Big-Screen Monitor by Digital Trends. Retrieved from <https://www.digitaltrends.com/computing/computer-monitor-buying-guide/> in November 2017.

² HDMI vs DisplayPort vs DVI vs VGA vs USB-C: Every Connection Explained Plus How to Get 144Hz by Expert Reviews. Retrieved from <http://www.expertreviews.co.uk/accessories/pc-monitors/1404476/hdmi-vs-displayport-vs-dvi-vs-vga-every-connection-explained> in November 2017.



Dual Monitor Configuration Offers Significantly Higher User Satisfaction

Single vs. Dual Monitor: Perceived Satisfaction (1=Lowest, 7=Highest)



Improving Employee Productivity with Dual Monitors. ³

For any comments, questions, and/or concerns with this technical brief, please contact VITA EA: ea@vita.virginia.gov

³ Improving Employee Productivity with Dual Monitors. IDC InfoBrief sponsored by Dell in November 2015. Retrieved from http://i.dell.com/sites/doccontent/shared-content/data-sheets/en/documents/dual_monitors_boost_your_productivity.pdf in November 2017.



Recommendation Supporting Information

Maximizing Your Multi-Monitor Setup. ⁴

- In a paperless office, your monitors are your principal workspace.
- A bigger workspace is an easy, inexpensive way to dramatically improve productivity.
- Think back to the paper era – would you work on a desk that only enabled you to see one sheet of paper at a time?
- An initial replacement investment is small, and it pays for itself in many different areas, including:
 - Higher productivity:
 - Studies have shown that a second monitor can increase the productivity of employees by 30% or more.
 - Productivity continues to increase with additional monitors.
 - More efficient workflow:
 - For a truly paperless workflow, multiple monitors are absolutely essential.
 - Reduced paper and printing costs:
 - Deploying multiple monitors dramatically reduces the number of paper documents that employees print during the course of their work.
- When adding additional monitors, it is important to arrange them in way that maximizes efficiency.
 - Especially important if deploying three or more monitors.
 - Human eyes tend to neglect information that is outside one's peripheral vision.
 - Ensure every monitor stays within the user's field of vision.

Productivity and Multi-Screen Computer Displays. ⁵

- One hundred eight university and non-university personnel participated in a comparison of single monitor, multi-monitor, and multi-monitor with local display configurations.
 - Respondents edited slide shows, spreadsheets and text documents in a simulation of office work, using each of the display arrays.

⁴ Maximizing Your Multi-Monitor Setup by Thompson Reuters in 2013. Retrieved from http://cs.thomsonreuters.com/resources/white-papers/Maximizing_Your_Multi-Monitor_Setup_white_paper.pdf in October 2017.

⁵ Productivity and Multi-Screen Computer Displays by the Rocky Mountain Communication Review in 2004. Retrieved from <http://www.tech-news.com/imagesap/utahdisplaystudy.pdf> in October 2017.



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- Performance measures, including task time, editing time, number of edits completed, and number of errors made and usability measures evaluating effectiveness, comfort, learning ease, time to productivity, quickness of recovery from mistakes, ease of task tracking, ability to maintain task focus and ease of movement among sources were combined into an overall evaluation of productivity.
- Multi-screens scored significantly higher on every measure.
- Even with increased monitor size, the single screen presents fundamental problems with window placement, stacking and tracking windows, multiple applications on the task bar, and the like. (Delefino, 1993; Grudin, 2003).
- Results: Multi-screen configurations scored significantly higher in usability than the single screen on every measure in every task.
 - The effect of screen configurations is quite clear; respondents were able to get on task quicker, do the work faster, and get more of the work done with fewer errors in multi-screen configurations than with a single screen. The gains are solid:
 - 33 percent fewer errors.
 - 18 percent faster in errorless production.
 - 16 percent faster in production.
 - 10 percent more production.
 - 7 percent faster on task.
 - 6 percent quicker to task.
 - Equally impressive is that these gains were achieved by turning on an extra monitor or two and providing five minutes of training.
- Respondents considered multi-screen configurations significantly more useful than single screen on every usability measure.
 - Multi-screens were seen as:
 - 45 percent easier for task tracking.
 - 38 percent easier to move around sources of information.
 - 32 percent faster to productive work.
 - 29 percent more effective for tasks.
 - 28 percent easier in task focus.
 - 24 percent more comfortable to use in tasks.
 - 19 percent easier for recovery from mistakes.
 - 17 percent easier to learn.
 - These increases were immediate post-test gains.
 - There was some evidence of a relationship between optimum monitor size and the optimum number of monitors.



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- The gains provided by an additional monitor in a three-monitor array can apparently be offset if the monitors are too large, forcing the user to physically track across the screens with head movement.
- Given the overwhelming consistency of both the performance and usability measures, multiple monitor configurations are recommended for use in any situation where multiple screens of information are an ordinary part of the work.
- There will be measurable gains in productivity, and the work will be judged as easier to do.
- Because the gains are strong, multiple monitors are also recommended as cost effective where multi-screen tasks represent as little as:
 - 15 percent of the work for the highly competent.
 - 17 percent for entry level competence.
 - 21 percent for the general work force.

How Multiple Monitors Affect Wellbeing. ⁶

- The ability to arrange monitors and easily control their position greatly affects productivity, comfort and wellbeing.
- For many tasks, multiple monitors offer definite advantages over a single screen.
- Small portable screens can't replace desktop displays.
- According to research, multiple screens can dramatically boost productivity.
 - One of the first indicators was a landmark study by researchers at the University of Utah.
 - The researchers found that multiple screens were "significantly more usable than single screens on measures of effectiveness, comfort, learning ease, time to productivity, mistake recovery" and other factors.
 - 98% of users preferred a dual monitor configuration to a single monitor.
 - Subsequent research since the Utah study has shown similarly impressive results.

⁶ How Multiple Monitors Affect Wellbeing by Steelcase in 2015. Retrieved from <https://www.steelcase.com/research/articles/topics/wellbeing/how-multiple-monitors-affect-productivity-and-wellbeing/> in October 2017.



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- Microsoft researchers found that switching to multiple monitor configurations could boost productivity between 9 percent and 50 percent.
- Tech consultant Jon Peddie reported users of multiple monitors estimated productivity gains averaging 42 percent.
- Researchers at Wichita State University found that multiple monitors helped boost performance, regardless of screen size.
 - Users reported dual monitors were measurably more efficient and less frustrating than a single monitor.
 - Perhaps most notable, nearly all of the study participants—98 percent – preferred a dual monitor configuration.
- Additional monitors allow users to:
 - Display more content (more windows, and in larger sizes).
 - Use more applications simultaneously, and switch between them more quickly.
 - View multiple windows without moving windows front to back, resizing, etc.
 - View documents side by side, cutting and pasting, etc.
- Multiple monitor configurations are growing in popularity: They're beneficial for any worker.

Increase Workplace Productivity through Intelligent Display Features and Design. ⁷

- Users found they saved time previously spent switching between applications and windows, and gained greater control over their workspace.
- Increasing screen space increases productivity.
- Large widescreen monitors can be equally or more productive than dual screen monitors.
- Use cases for increasing productivity through the use of greater screen space include:
 - Programming
 - Writing/editing
 - Spreadsheets
 - Design
 - Multitasking

⁷ Increase Workplace Productivity through Intelligent Display Features and Design by Viewsonic in February 2015. Retrieved from <https://www.viewsonic.com/mwg-internal/de5fs23hu73ds/progress?id=cmvPts4ZLcONGQyU-TNhp8hPmvy8GMqEquAnNewmPA0.&dl> in October 2017.



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Top 5: Reasons to use a widescreen monitor. ⁸

- Five ways a wider monitor (29" – 34") can help you be more productive:
 - A glance is faster than a click.
 - If you have to bring a window forward it slows you down and over time can eat into how well you're getting things done.
 - The Windows start screen actually becomes useful.
 - All those tiles make sense in a nice wide screen where a start menu can be tiny and hard to see.
 - It's more flexible.
 - With one big widescreen you can emulate two or four separate monitors or even do a picture in picture (PIP), whatever fits the project you're working on at the time is best.
 - With physically separate monitors that's problematic.
 - It cuts down on hardware.
 - Instead of couple 20-inch monitors you might find a 34-inch monitor gives you all the viewing space you need.
 - Plus, it may be easier not having that gap between two monitors.
 - Easier IT hardware procurement policy.
- Join the expansive life of the widescreen monitor.

Ultrawide vs Dual Monitors: Which Are Better for Productivity? ⁹

- Using a 34" ultrawide is a lot like that feeling you had the first time you put two monitors on your desk and marveled at how much room you had to work.
 - The Bottom Line: Ultrawides are a great alternative to multiple monitors.
- If you like having your displays angled a little on either side of your desk, curved displays are especially nice.
- The number of monitors you have doesn't matter when it comes to productivity; it's the actual real estate those monitors offer that matters, and how you use it.

⁸ Top 5: Reasons to use a widescreen monitor by Tom Merritt of TechRepublic in September 2017. Retrieved from <https://www.techrepublic.com/article/top-5-reasons-to-use-a-widescreen-monitor/?bhid=26606203755366905506601539607666&ftag=TRE684d531> in October 2017.

⁹ Ultrawide vs Dual Monitors: Which Are Better for Productivity? By Alan Henry of LifeHacker in April 2015. Retrieved from <https://lifelife.com/ultrawide-vs-dual-monitors-which-are-better-for-product-1695967682> in October 2017.



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- If you have two or three tiny displays and you still scroll and struggle to work with the documents, spreadsheets, and web pages you need to read, they're not helping you.
- Instead, one, really large display that can accommodate all of that information cleanly (or rotating it so it's vertical) would be a bigger boon for you.
- At 34", you start to have more than enough room to work.
 - With resolutions like 3440 x 1440, you have enough space to open up three or four browser windows, documents, or applications side-by-side or tiled without text getting too small to read, and menus impossible to navigate.
- The benefits of an ultrawide monitor only really appear once you get over 30", or bigger and wider than most people already work with one or two displays.

The Benefits of Using Windows 10 on a 34-inch Ultrawide Monitor. ¹⁰

- The author has been taking advantage of a multiple-monitor configuration ever since the feature first became available in Windows 98.
- One of the biggest advantages the author finds to a multiple-monitor configuration is the amount of time and effort he saves when doing any type of multitasking, such as running multiple applications.
 - Rather than maximizing and minimizing windows to switch between apps, the author simply glances from one monitor to the other.
- Author found that using the Windows 10 Start screen on a 34" ultrawide monitor provided an easier-to-use menu system; he can't go back to the previous Windows' (8, 7, XP, etc.) start menu style.
- In fact, the author goes so far as to say that he's found that it is easier to work in two applications on a single monitor than to work in two applications on two monitors.
- On this ultrawide monitor, the windows are large enough to use four applications on one monitor, and get real work done very efficiently.

¹⁰ The benefits of using Windows 10 on a 34-inch ultrawide monitor by Greg Shultz of TechRepublic in January 2017. Retrieved from <https://www.techrepublic.com/article/using-windows-10-on-a-34-inch-ultrawide-monitor/> in October 2017.



Using the Multi-Display Teaching System to Lower Cognitive Load. ¹¹

- Multimedia plays a vital role in both learning systems and the actual education process.
 - Currently used presentation software is often not optimized and generates a great deal of clutter on the screen.
 - There is often insufficient space on a single display, leading to the division of content.
 - These limitations generally increase cognitive load.
 - Results showed multi-display instructional material significantly reduced cognitive load and enhanced learning effectiveness.
- The multi-display system is able to enlarge the displayable content and make more room for multimedia content in particular to be presented clearly.
- The experimental results show the multi-display teaching system proposed in this paper does actually decrease cognitive load and efficiently improves learning performance.

Case Study: Nationwide Insurance – Employees Enjoy Rich and Vibrant Colors with Samsung LED Monitors. ¹²

- Nationwide Insurance needed to refresh its LCD monitors with a solution that its employees would want and IT could support.
- When it came time to refresh aging 19" LCD monitors, Nationwide provided employees an opportunity to review, rate, and vote for a preferred monitor.
- In the process, Nationwide learned employees preferred a step up to 24-inch displays from the current 22-inch displays in use.
- Results: Nationwide was able to meet the needs of 46,000 employees and IT by choosing Samsung commercial-grade displays.
 - Employees got a 16% larger monitor size, truer colors, and improved ergonomics while IT was able to provide employees their preferred choice without breaking the budget.
- Nationwide also selected the 27-inch Samsung 850 series displays for its technical staff.
 - With larger displays and 2560 x 1440 resolution, the 850 series improves productivity and efficiency for Nationwide's engineers, programmers, and network designers.

¹¹ Using the Multi-Display Teaching System to Lower Cognitive Load by The Journal of Educational Technology and Society in 2004. Retrieved from http://www.ifets.info/journals/18_4/11.pdf in October 2017.

¹² Case Study: Nationwide Insurance – Employees Enjoy Rich and Vibrant Colors with Samsung LED Monitors in July 2015. Retrieved from http://s7d2.scene7.com/is/content/SamsungUS/b2b/resource/2015/08/04/b2b_resource_Case-Study_Nationwide-Insurance_Monitor_JUL15KC.pdf in October 2017.



Enterprise Architecture End-User Displays

- The higher resolution 27-inch Samsung 850 series gives Nationwide's more technical employees the room to see more and do more.
- In many cases, the 27-inch displays are used in dual-monitor mode, providing even more work landscape for engineers and programmers to see more lines of code more clearly than before.

With Similar Visual Angles, Larger Displays Improve Spatial Performance by Carnegie Mellon University's School of Design. ¹³

- We believe there is an emerging trend in the workplace towards multiple displays, which have the potential to provide abundant display space distributed throughout the environment.
- Users performed about 26% better on a task requiring mental rotation when working on the large display.
- Overall, our results demonstrated a benefit to working on a large display.

A Survey of Large High-Resolution Display Technologies, Techniques, and Applications by University of California, Davis and Pacific Northwest National Laboratory. ¹⁴

- The increasing popularity of large high-resolution displays is paralleled by booming research efforts in addressing a fundamental question: How do users benefit from increased size and resolution?
- Multi-monitor (aka "multimon") is an increasingly popular configuration in businesses and homes to extend a standard desktop PC with more screen real estate.
- Large high-resolution displays offer the sense of scale needed for geospatial imaging and large film-quality video applications.
 - The ability to obtain realistic terrain representations, zoom across scales, and create fly-through animations certainly benefits geospatial visualization.
- Large displays allow users to see critical details in complex dynamic phenomena, such as subtle eddies that are critical to understanding global ocean circulation models.

¹³ With Similar Visual Angles, Larger Displays Improve Spatial Performance by Carnegie Mellon University's School of Design in April 2003. Retrieved from <http://sbabu.people.clemson.edu/p217-tan.pdf> in October 2017.

¹⁴ A Survey of Large High-Resolution Display Technologies, Techniques, and Applications by University of California, Davis and Pacific Northwest National Laboratory. Retrieved from http://graphics.cs.ucdavis.edu/~staadt/download/NiSchmidtStaadT_et_al_VR06.pdf in October 2017.



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- With LCD panels becoming less expensive, it is an emerging trend to have personal multi-monitor configurations in offices.
- In the first study, participants encountered a significant performance gain on the large display.
 - In the second study, not surprisingly, users were more effective on the physically larger display.
 - They suggested that large displays may afford a greater sense of presence, leading users to adopt an egocentric rather than an exocentric strategy in spatial tasks.

Effect of Display Size on Users' Search Performance by the University of Stuttgart, Germany in April 2015. ¹⁵

- A substantial body of work showed positive effects of large high-resolution screens on exploring large data sets.
- Users perform tasks faster and more precise when using large screens.
- In general, the feedback from our participants indicates the use of large and high-resolution displays is more beneficial to discover similarities and trends in large data sets.

Increased Display Size and Resolution Improve Task Performance in Information-Rich Virtual Environments. ¹⁶

- We have presented a controlled experiment to evaluate the effects of increased display size and resolution on task performance.
 - A factorial experimental design approach was adopted in which display size and resolution were treated separately and altered at two levels.
- Our results replicate and extend prior insights into benefits of large displays in improving spatial navigation performance.
 - In fact, we have shown that users working with large high-resolution displays were most effective in performing various navigation, search, and comparison tasks.
 - We therefore conclude the increased display size and resolution reliably improve task performance.

¹⁵ Using Space: Effect of Display Size on Users' Search Performance by Stuttgart University in Germany in April 2015. Retrieved from http://katrinwolf.info/wp-content/uploads/2015/07/large_screen2.pdf in October 2017.

¹⁶ Increased Display Size and Resolution Improve Task Performance in Information-Rich Virtual Environments by the Department of Computer Science at Virginia Tech. Retrieved from <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.99.5117&rep=rep1&type=pdf> in November 2017.



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Improving Employee Productivity with Dual Monitors. ¹⁷

- Businesses are moving toward providing employees with more screen real estate, either via larger screen size or via dual monitors.
- Users complete tasks at hand quicker and with more accuracy with dual monitor configuration.
- Monitor upgrades are low-cost hardware investments that can have big impacts on employee productivity and satisfaction.
- Multimonitor configurations allow office workers to multi-task with multiple applications (e.g., word processing or spreadsheet on one screen and email on the other).
- Provide employees with multiple monitor setups early in their tenure so they can benefit from productivity gains immediately.
- Think about dual monitor configurations for shared work space (hot desk) environments to ensure employees who frequently use dual monitor setups don't have productivity loss, and those that don't have dual monitor setups learn the benefits.
- For office workers where information is a large part of their workflow, dual monitor configurations are a must.

When One Isn't Enough: An Analysis of Virtual Desktop Usage Strategies and Their Implications for Design by Stanford University Computer Science Department. ¹⁸

- Screen space is a limited resource for computer users – multiple monitors are one means of workspace expansion.
- People used their extra monitor as a place for keeping secondary applications, such as email, while their main monitor (often larger and/or higher resolution) was devoted to their primary task.

Washington State Office of Financial Management – Information Technology Upgrade Policy Review. ¹⁹

- A number of factors drive the useful life of technology.

¹⁷ Improving Employee Productivity with Dual Monitors. IDC InfoBrief sponsored by Dell in November 2015. Retrieved from http://i.dell.com/sites/doccontent/shared-content/data-sheets/en/documents/dual_monitors_boost_your_productivity.pdf in November 2017.

¹⁸ When One Isn't Enough: An Analysis of Virtual Desktop Usage Strategies and Their Implications for Design by Stanford University Computer Science Department. Retrieved from <http://cs.stanford.edu/~merrie/papers/vmon.pdf> in October 2017.

¹⁹ Washington State Office of Financial Management – Information Technology Upgrade Policy Review by the Enterprise Management Group (EMG) IT Upgrade Review Work Group. Retrieved from <https://ofm.wa.gov/sites/default/files/public/legacy/budget/info/itupgrade.pdf> in November 2017.



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- Reliable technology tends to maximize worker productivity.
- Investments in desktop technologies are no longer a one-time expense, but an on-going cost of doing business.
- Increasing business requirements, frequent technology changes and technology support costs drive the need for recurring IT replacements.
- Lagging IT replacement cycles present challenges for state government such as:
 - Incompatibility of office automation products causing problems with communications and/or information-sharing within or among agencies.
 - Time to locate replacement parts or “cannibalize” them from other equipment.
 - Undefined replacement cycles can result in inconsistent and less predictable budget requirements, equipment dollars being reallocated, and unexpected expenses when equipment fails and has to be replaced.
- Replacement of computing hardware and software is most often driven by factors outside the control of individual agencies such as:
 - “Domino” effect of hardware and software advances; a change in one requires a change in the other.