control system vulnerabilities
> analysis of 5 years of field data

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[on behalf of the DHS CSSP
program - INL contract #240704]

outline

- background on the project
- review of ISA99 architecture model
- source for data used in the analysis
- interesting results
  - avg. # of days between vulnerability disclosure and discovery
  - where in the architecture are most vulns being discovered
  - does the type of vulnerabilities change throughout the architecture
  - workstation HMI vulnerabilities ranked by OS
  - network vs. host/application vulns throughout the architecture
  - interesting security findings on control system networks
- Q & A …and video clip of new control system defense prototype

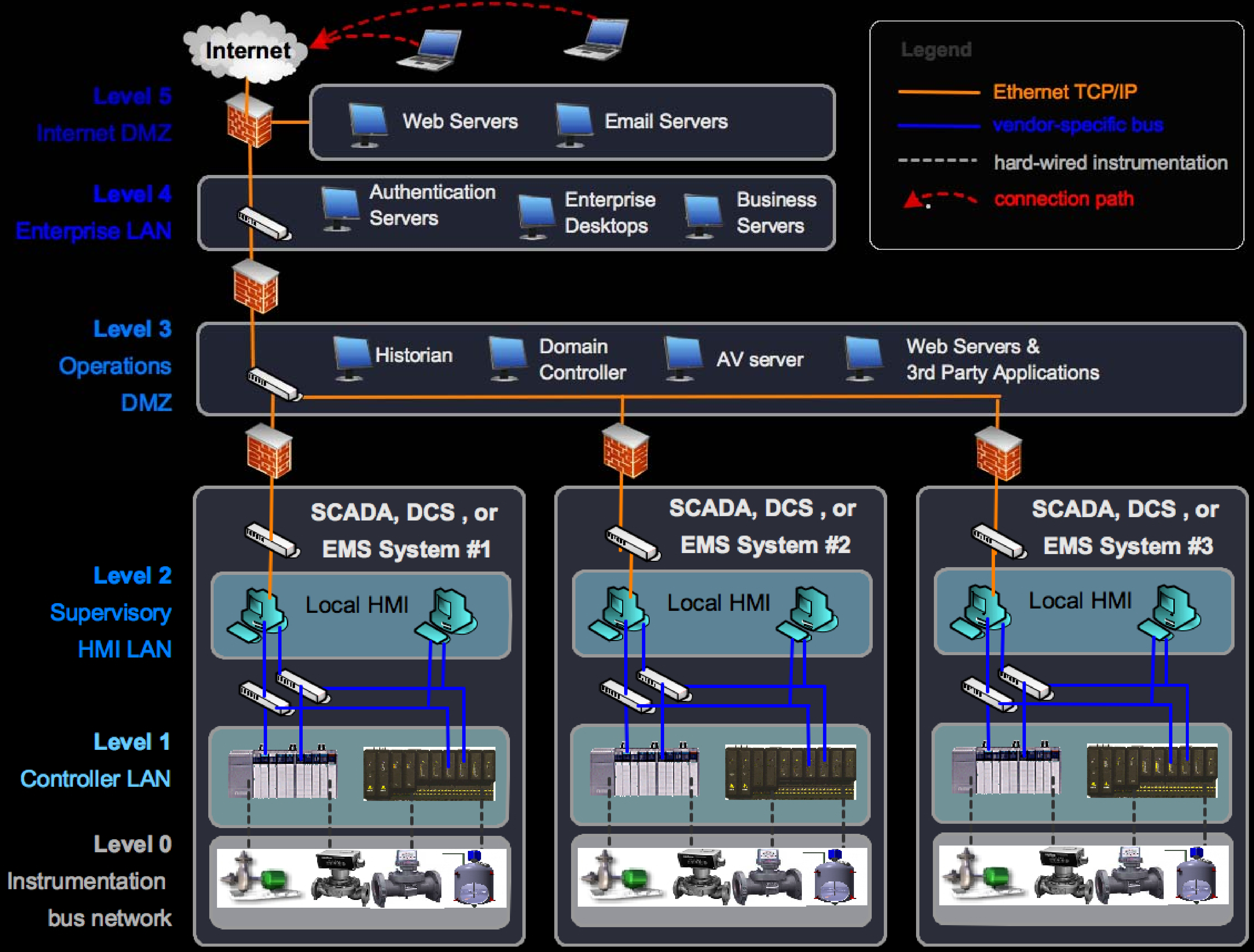
project background

- Over 38,000 control system vulnerabilities collected over 5 years from mid-2002 to 2008 [plantdata and industrial defender]

- Over 100 security assessments performed on critical infrastructure facilities such as electric power generation plants, transmission energy control centers, chemical plants, water plants, and oil/gas production, refining, and pipeline systems

- Vulnerability analysis and classification conducted under research project facilitated by INL and funded through the DHS Control Systems Security Program contract #240704

- ISA99 architecture model used to classify where the vulnerabilities were discovered in the systems



Legend

Ethernet TCP/IP

vendor-specific bus

hard-wired instrumentation

connection path

Internet

Level 5
Internet DMZ

Web Servers

Email Servers

Level 4
Enterprise LAN

Authentication Servers

Enterprise Desktops

Business Servers

Level 3
Operations
DMZ

Historian

Domain Controller

AV server

Web Servers & 3rd Party Applications

SCADA, DCS , or EMS System #1

SCADA, DCS , or EMS System #2

SCADA, DCS , or EMS System #3

Level 2
Supervisory
HMI LAN

Local HMI

Level 1
Controller LAN

Level 0
Instrumentation
bus network

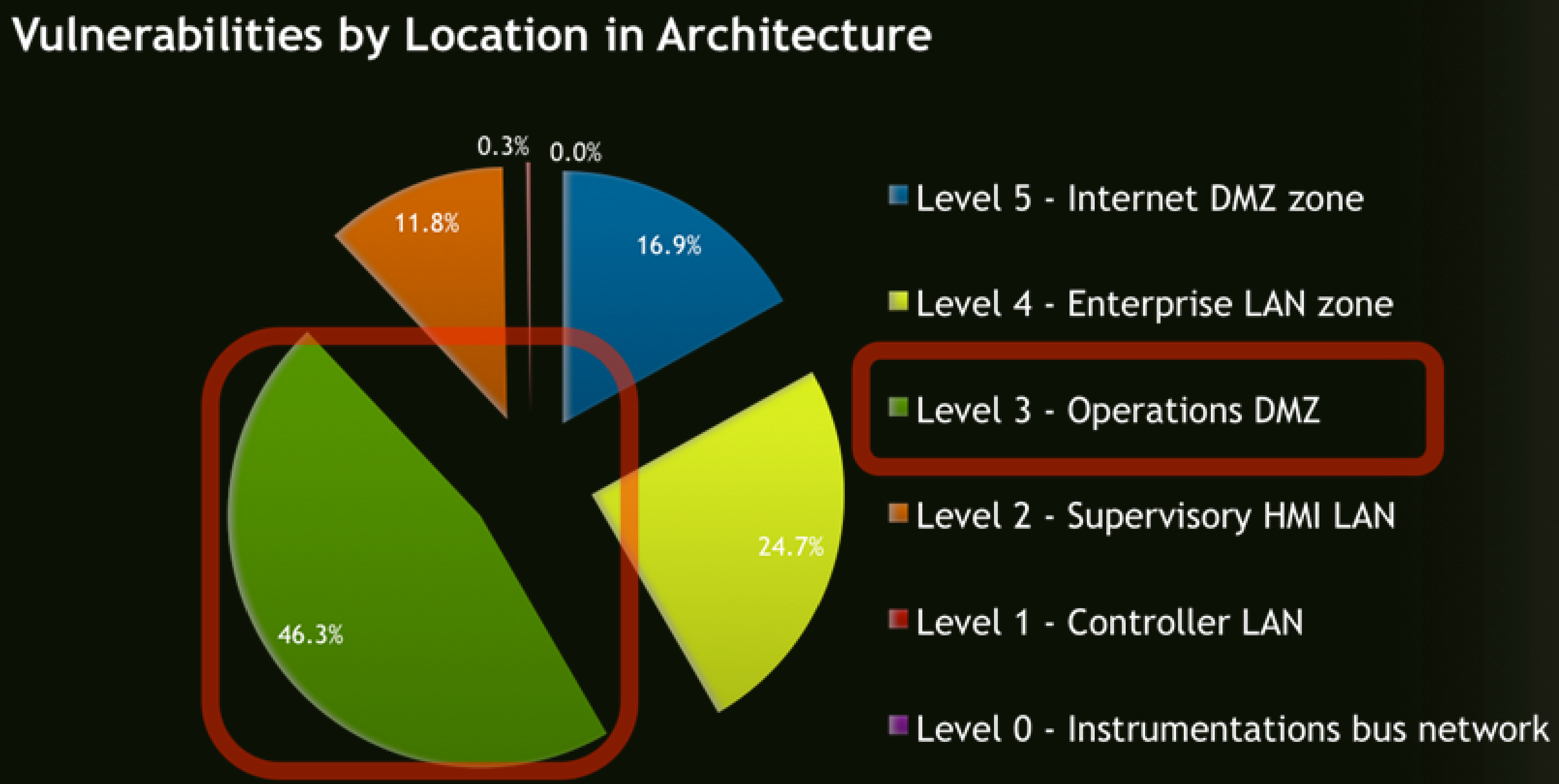
data source – what was collected?

- From mid-2002 to 2008, vulnerability data was stripped of any client information and the raw vulnerabilities were captured in a database
  - Vulnerability ID (auto-numbered from entry number 1)
  - Vulnerability Title (title for the vulnerability)
  - Security Zone or Location (location based on the ISA99 model where the vulnerability was located)
  - Disclosure Date (date when vulnerability was disclosed)
  - Discovery Date (date when vulnerability was discovered by the team and entered into the database)
  - Days Between Disclosure and Discovery (time between disclosure and detection)
  - Vulnerability Detailed Description
  - Vulnerability Suggested Remediation Steps

interesting results

- avg. # of days between vulnerability disclosure and discovery
  - all field data was exported from the database to an excel spreadsheet containing over 38,000 rows, and much of the analysis had to be performed manually
  - since we captured when the vulnerability was disclosed in the public, and also captured when the vulnerability was discovered and entered into the database, we were able to perform a simple diff against these two fields
  - vulnerabilities that were never disclosed in the public were thrown out of this particular exercise since negative or zero entries would throw off the calculations
  - the maximum number of days between when a vulnerability was disclosed in the public and when it was found during an assessment was over 3 years!
  - the average was 331 days, or close to 1 year. this means that on average most SCADA and process control environments contained latent vulnerabilities, probably with compiled exploits, and were not discovered until almost a year later, and would not have been discovered had not the asset owner funded the assessment.

where are the vulnerabilities being discovered?

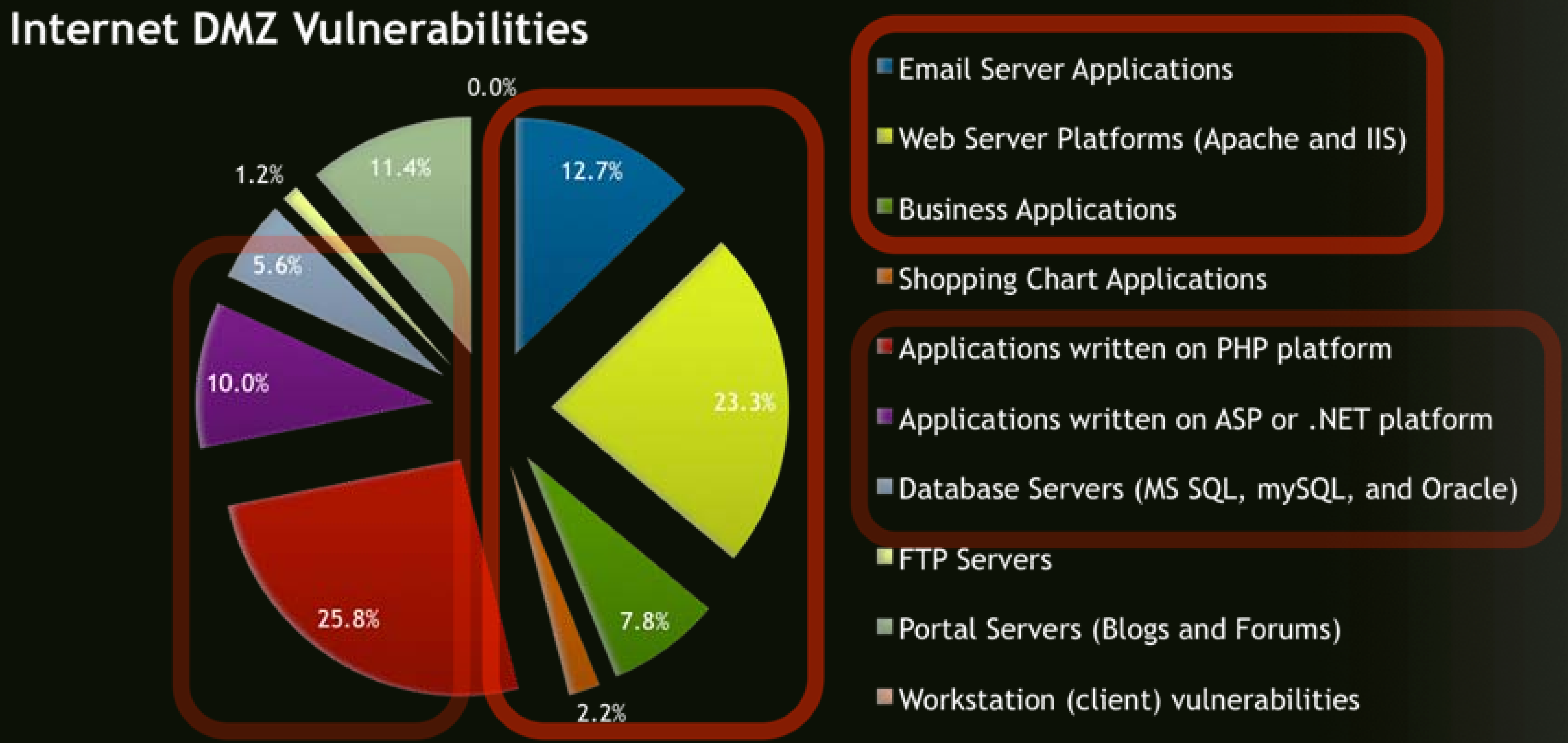

Vulnerabilities by Location in Architecture

does the type of vulnerabilities change throughout the architecture?

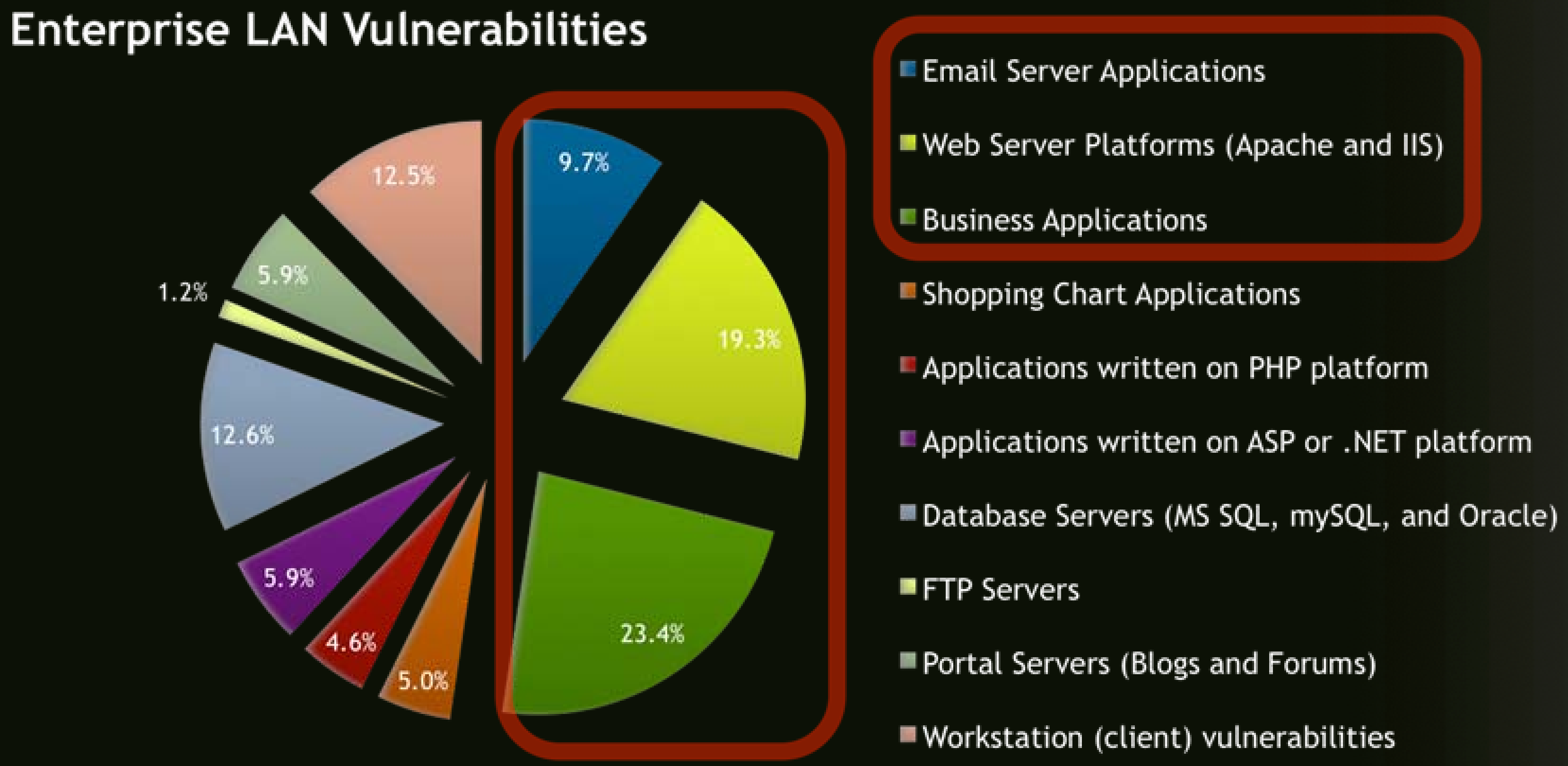
- classified each vulnerability by the system that was impacted and where the vulnerability was found in the architecture

- The data set emerged a common set of system types at each network zone or segment:
  - Email Server Applications
  - Web Server Platforms (Apache and IIS)
  - Business Applications
  - Shopping Cart Applications
  - Applications written on PHP platform
  - Applications written on ASP or .NET platform
  - Database Servers (MS SQL, mySQL, and Oracle)
  - FTP Servers
  - Portal Servers (Blogs, Forums, etc…)
  - Workstation (client) vulnerabilities

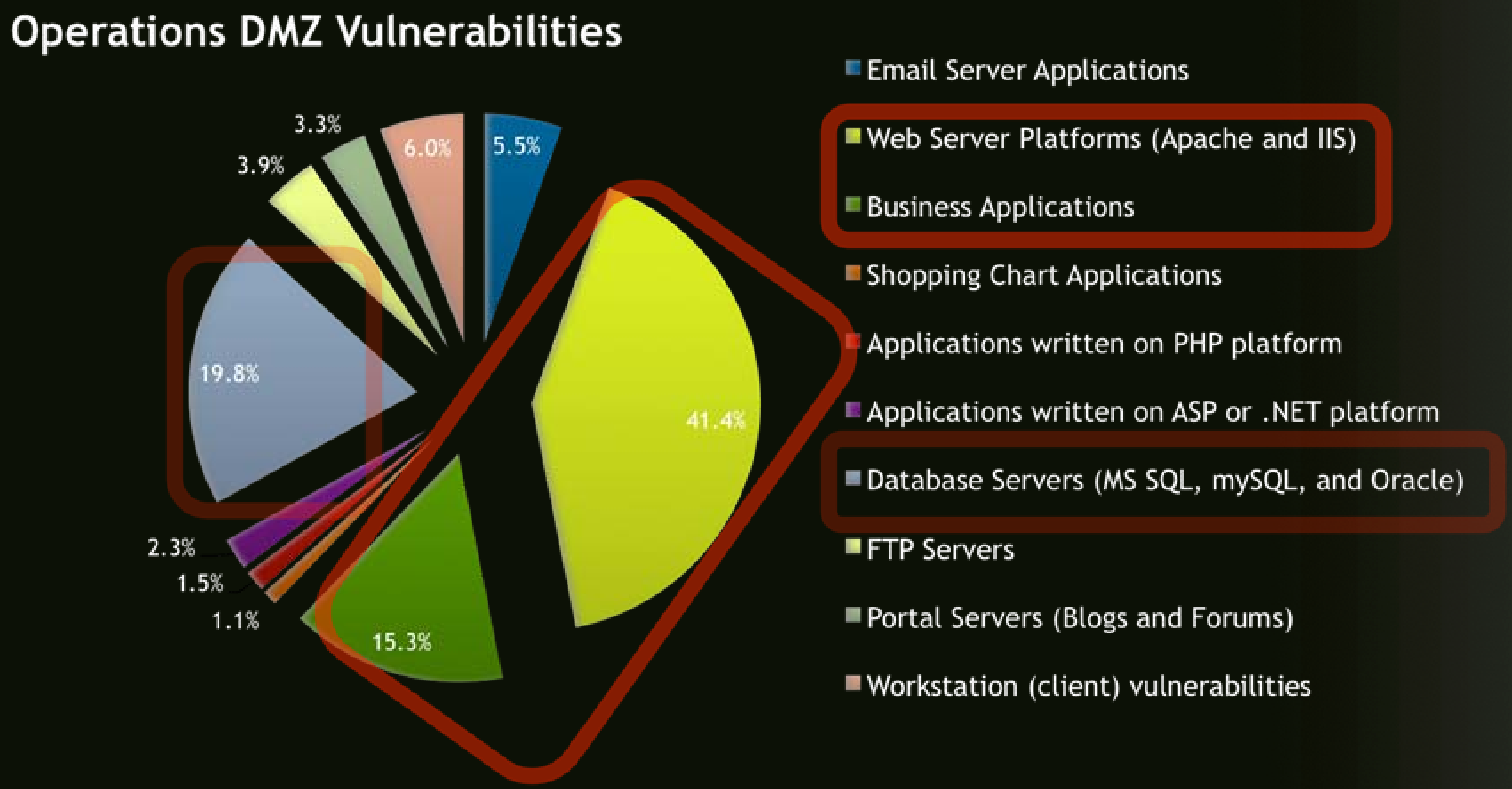
systems impacted at the Internet DMZ zone



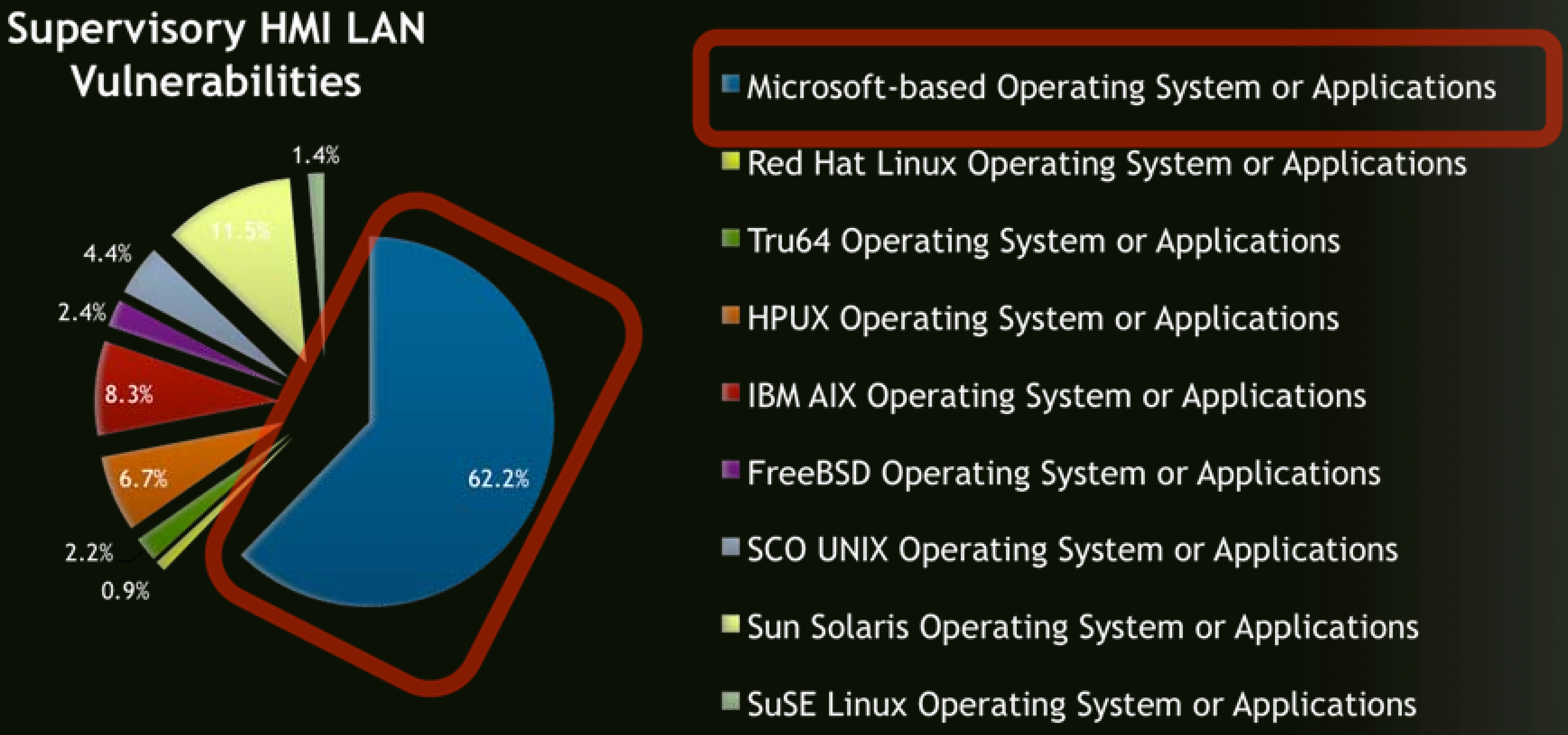
systems impacted at the Enterprise LAN zone



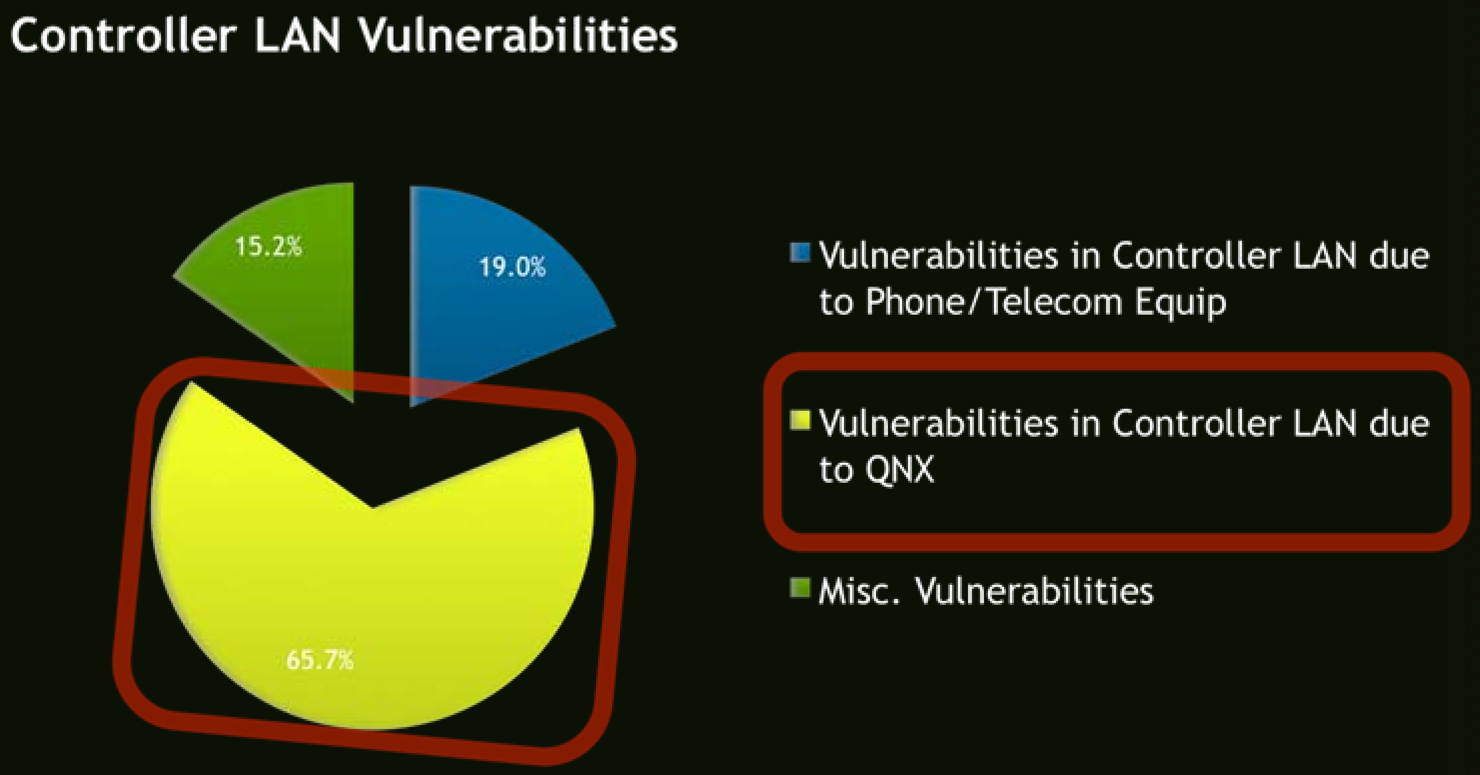
systems impacted at the Operations DMZ zone



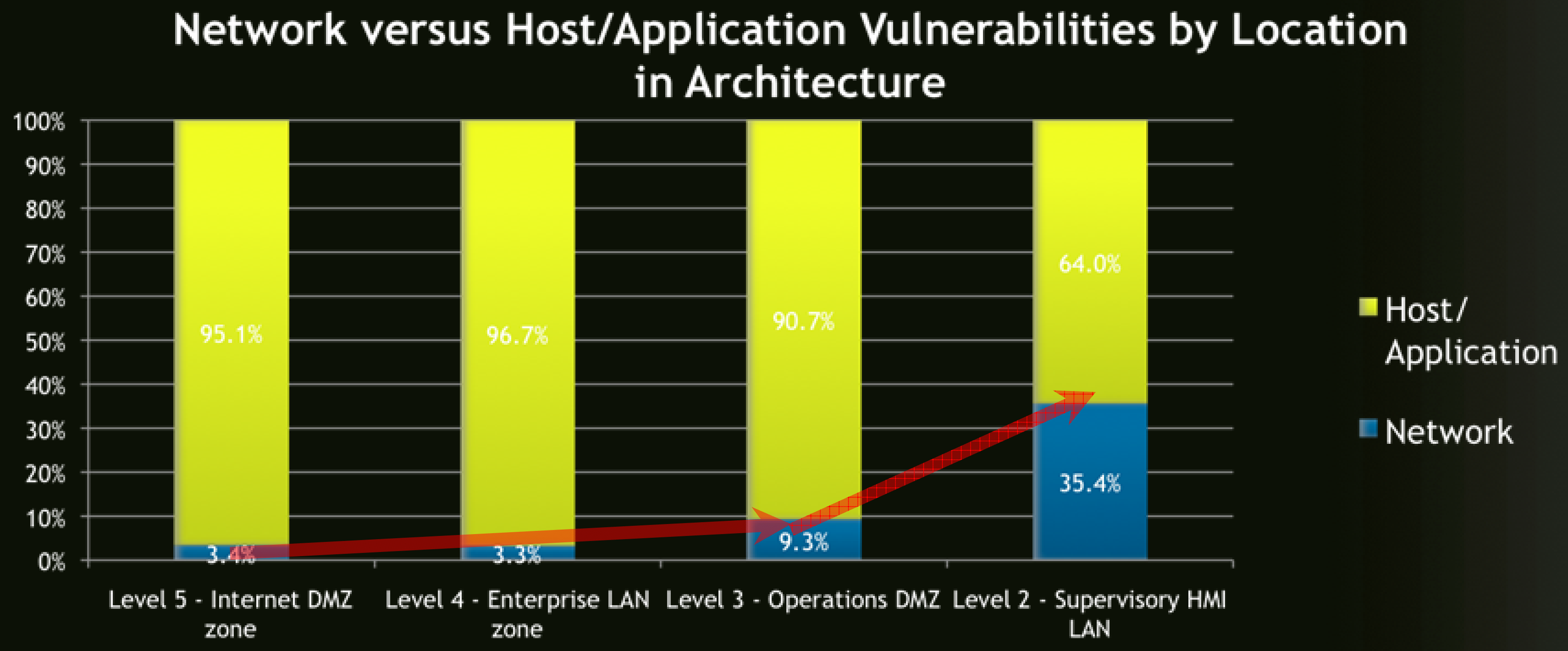
workstation HMI vulnerabilities ranked by OS



only logged 105 controller LAN vulnerabilities, but QnX showed up as the most typical source



network vs. host/application vulns throughout the architecture



interesting security findings on control system networks

- VOIP (Voice over IP) Systems
- Network Video Recording Devices
- Network Surveillance Equipment and Software
- Adult Video Directory Scripts
- Online Dating Service Databases
- Advanced Forensics Format (AFF) archives
- Gaming Software Servers
  - aGSM - a freeware game server info monitoring utility
  - Alien Arena 2006 Gold Edition
  - Counter Strike
  - Brood Wars
  - Battlefield 1942 Server and Clients
  - Quake 2 and Quake 3 Game Servers found in Supervisor HMI LAN
  - Soldier of Fortune II
- Software license cracking executables (CD-key generators)
- Torrent client software on Supervisor HMI LAN
- Paging Software Server (i.e. Air Messenger Server connected to both the SCADA and Internet for SMTP relay out)
- America Online Clients
- MP3 Music and Video Playing Software including iTunes
- Streaming Music and Radio software with vulnerabilities
- BitTorrent Clients (for peer-to-peer file sharing)
- MSN and other IM chat clients
- Anonymous FTP Servers running waiting for connections

but wait…there's more

- Apache Web Servers and Linux hosts un-patched for over 2 years
- APC Battery Backup UPS systems with vulnerable Web Interface
- Several web blog site engines running in control system DMZ
- Office grade Linksys, Belkin, and D-Link WiFi devices on Supervisory HMI LAN
- IM clients found installed and contained vulnerabilities on Supervisory HMI LAN
- Windows 95 found installed on hosts in Supervisory HMI LAN (no longer supported by MS)
- Windows NT found installed on hosts in Supervisory HMI LAN (no longer supported by MS)
- Windows Vista found used as OS for operator consoles in Supervisory HMI LAN
- IRC Chat Servers found installed on hosts in the Operational DMZ LAN
- Nintendo Entertainment System (NES) Game Simulator
- Netscape Browser vulnerabilities detected in Supervisor HMI LAN
- Multi-function Printer/Fax/Scanner device vulnerabilities

summary / take away points

- vulnerability classification is difficult, time consuming, and manual if the correct fields are not captured up front > *is there benefit in a common format*?
- 331 = the average time in days between when a vulnerability was disclosed in the public versus when it was discovered in an industrial control systems assessment
- the intermediate Operations DMZ network that sites between the Enterprise network and the industrial control systems had the most vulnerabilities attributed to its zone
- web server and back-end database vulnerability findings comprised the largest number of vulnerabilities found in these Operations DMZ network – *we need more web app testing!*
- network devices are better managed in the Internet DMZ and Enterprise LAN networks where the IT or IS department has clear ownership of managing the network devices
- number of client workstation vulnerabilities also increased deeper into the real-time operations networks, thus proving we still have a patch problem in our industry
- vulnerabilities with Windows operating systems or Windows applications also accounted for the overwhelming majority of vulnerabilities for systems in the Supervisory HMI LAN

new prototype for a control system security defense system