Accelerator Technology Department

ATC/ABOC Days – Session 4

MTTR & spare policy for the LHC injectors & experimental areas: AT and IT

Ph. Lebrun – Chair

T. Smith – Scientific secretary

MTTR & Spare Policy for the LHC Injectors

Magnets for the PS Complex

T. Zickler

Magnet types

	Installed units	Magnet types
Linac 2 + TL	52	14
Booster	253	15
Booster TL	70	16
PS	243	24
TT2	49	9
Linac 3	40	19
Ion Beam Lines	47	20
LEIR	44	7
Total	**798**	**108**

All types:

Bending, combined function, corrector, dipole, multipole, octupole, quadrupole, sextupole, solenoid, water cooled, indirect water cooled, air cooled, iron-less, PFW, pulsed, continuous, etc…

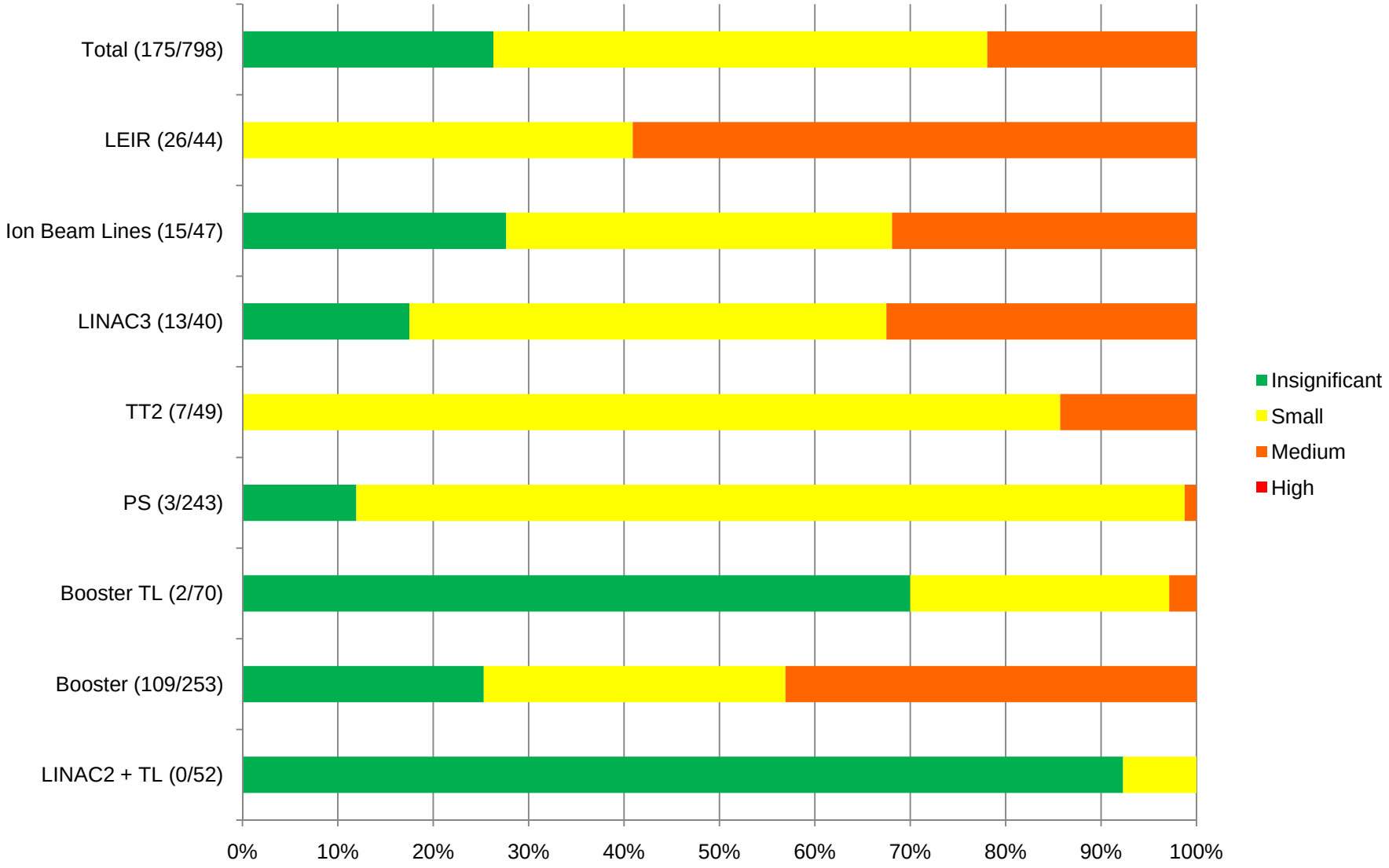
Typical problems and failures

Typical problems and failures which occur on magnets due to aging, radiation and fatigue, which lead to repair interventions or magnet replacement:

- Water leaks in cooling circuits
- Electrical short circuits to ground
- Obstructed cooling ducts
- Degradation of coil shimming
- Broken cable insulation
- Inter-turn short circuits

Pictures courtesy of A. Newborough and D. Bodart

Risk analysis - Results



Conclusion and Future

Situation OK for:

- Linac 2, PS, TT2

Spare situation to be improved for:

- Booster, Linac 3, Ion Beam TL, LEIR
- Total required: 800 kCHF, 3 FTE*y, 2 years delay

Extend magnet inventory to other machines and beam lines

- CTF3, AD, Isolde, East Hall EA, n-TOF, SPS, North Area

Complete data base

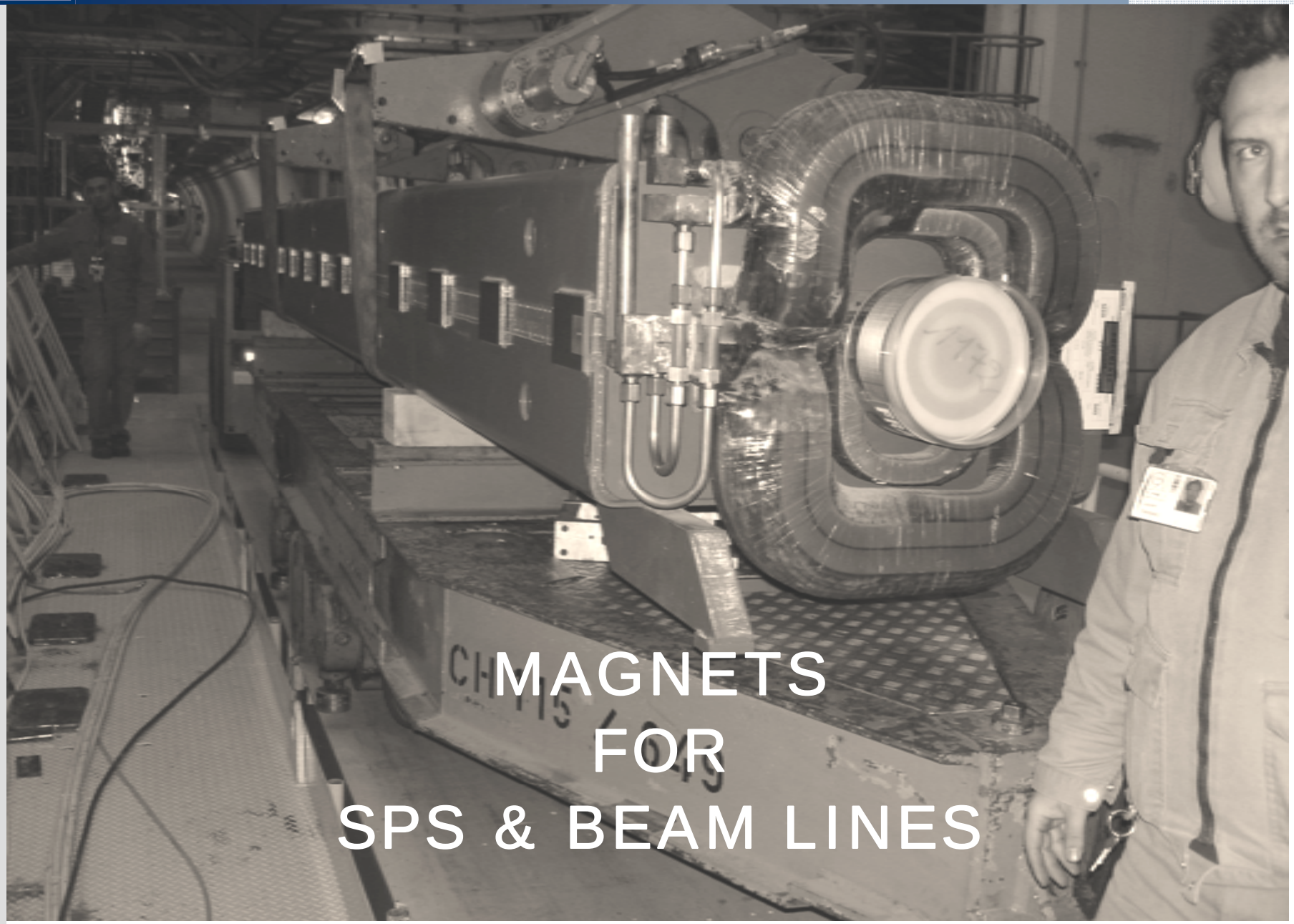
- Upload all relevant documents
- Link to layout data base to ease maintenance and traceability

Central storage for PS Complex magnets

- Regroup all spare magnets and magnet components in 150

Discussion

- Investigate the possible use of experimental area magnets as additional spares for the PS complex

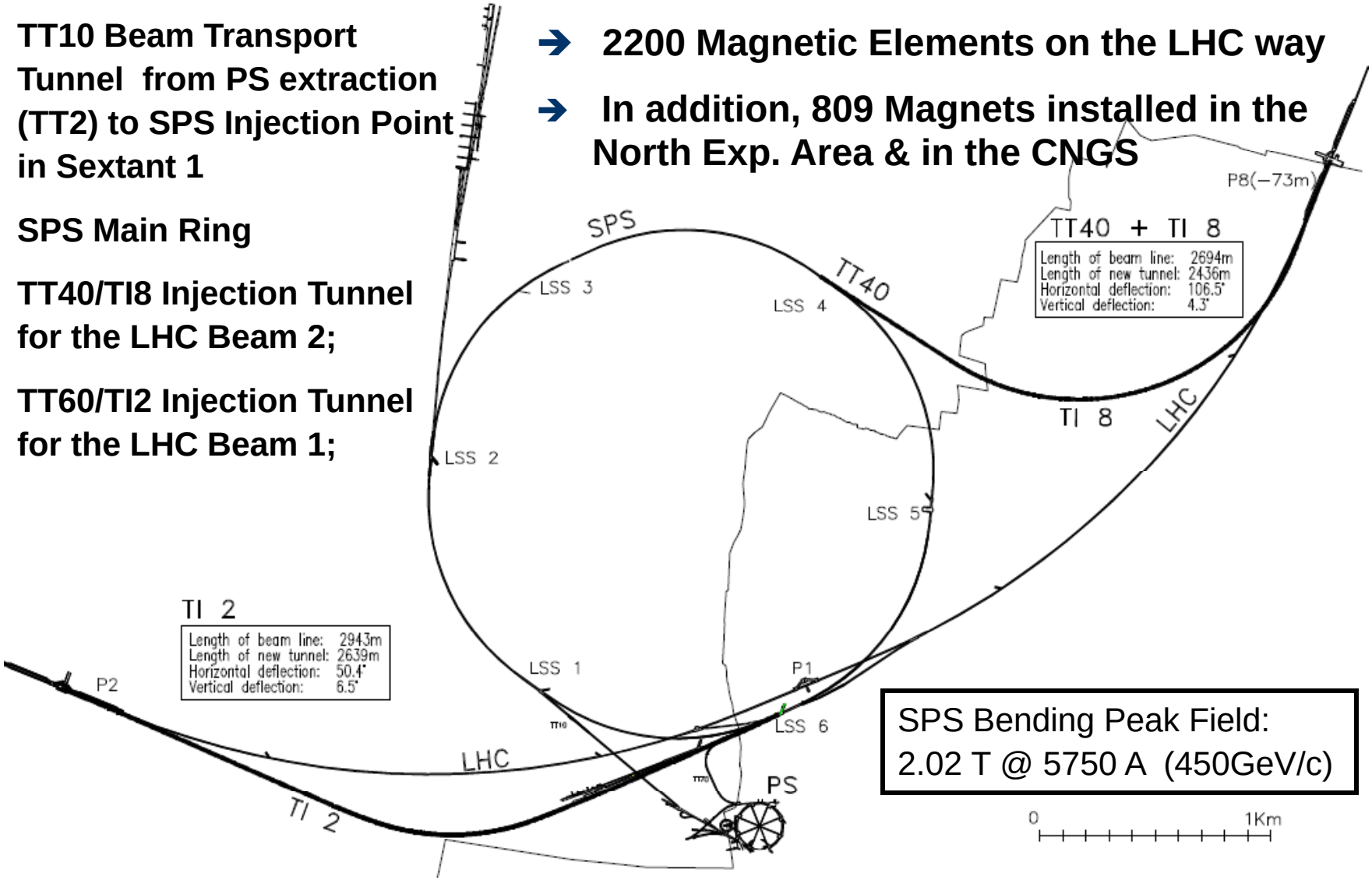

MAGNETS
FOR
SPS & BEAM LINES

SPS as LHC Injector : Overview of the Complex

SPS as LHC injector incorporates:

- ➔ **TT10 Beam Transport Tunnel from PS extraction (TT2) to SPS Injection Point in Sextant 1**
- ➔ **SPS Main Ring**
- ➔ **TT40/TI8 Injection Tunnel for the LHC Beam 2;**
- ➔ **TT60/TI2 Injection Tunnel for the LHC Beam 1;**

- ➔ **13500 m of Beam Lines**
- ➔ **2200 Magnetic Elements on the LHC way**
- ➔ **In addition, 809 Magnets installed in the North Exp. Area & in the CNGS**



SPS Bending Peak Field:
2.02 T @ 5750 A (450GeV/c)

3515 Magnets for the SPS Complex (80 families)

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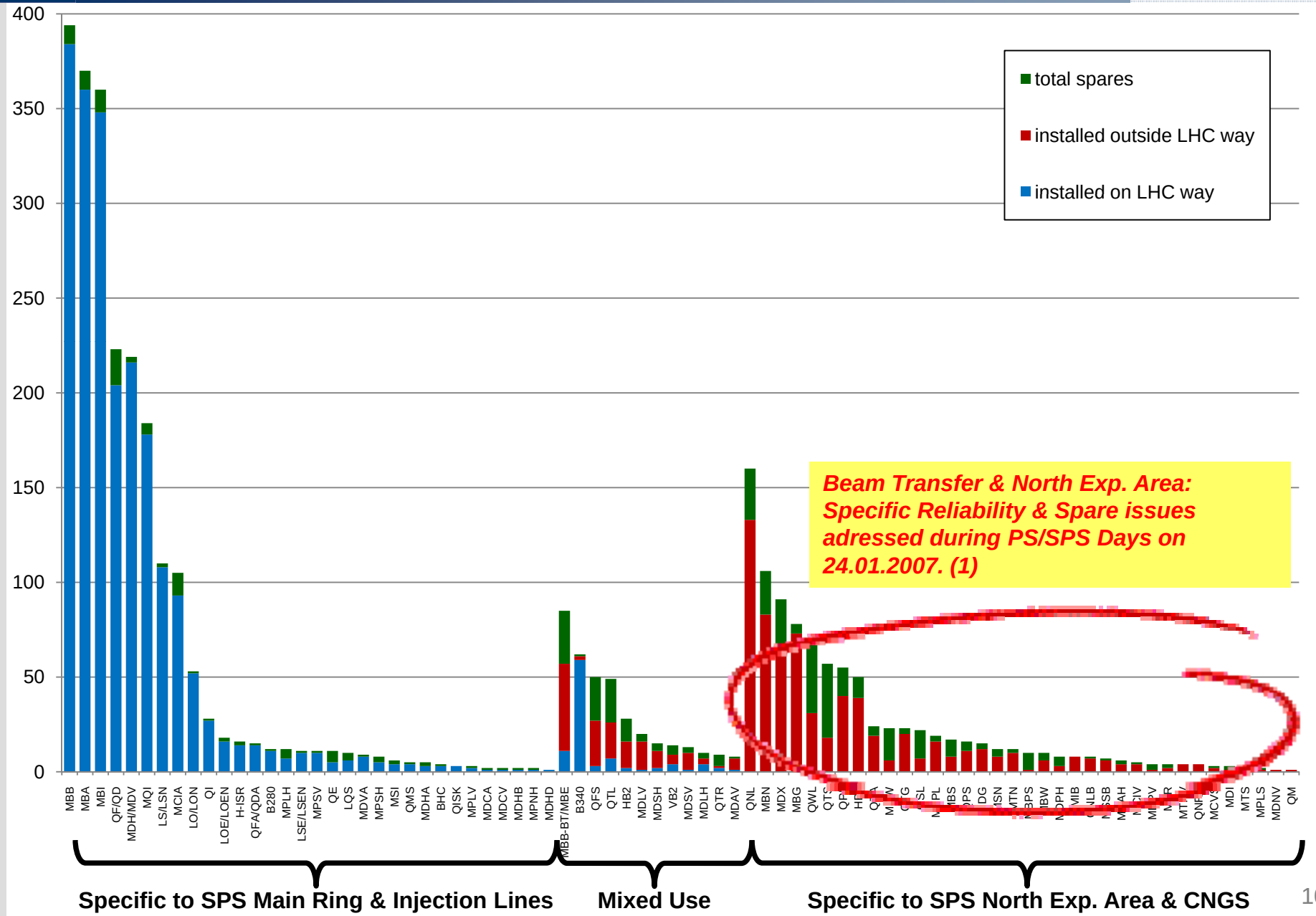
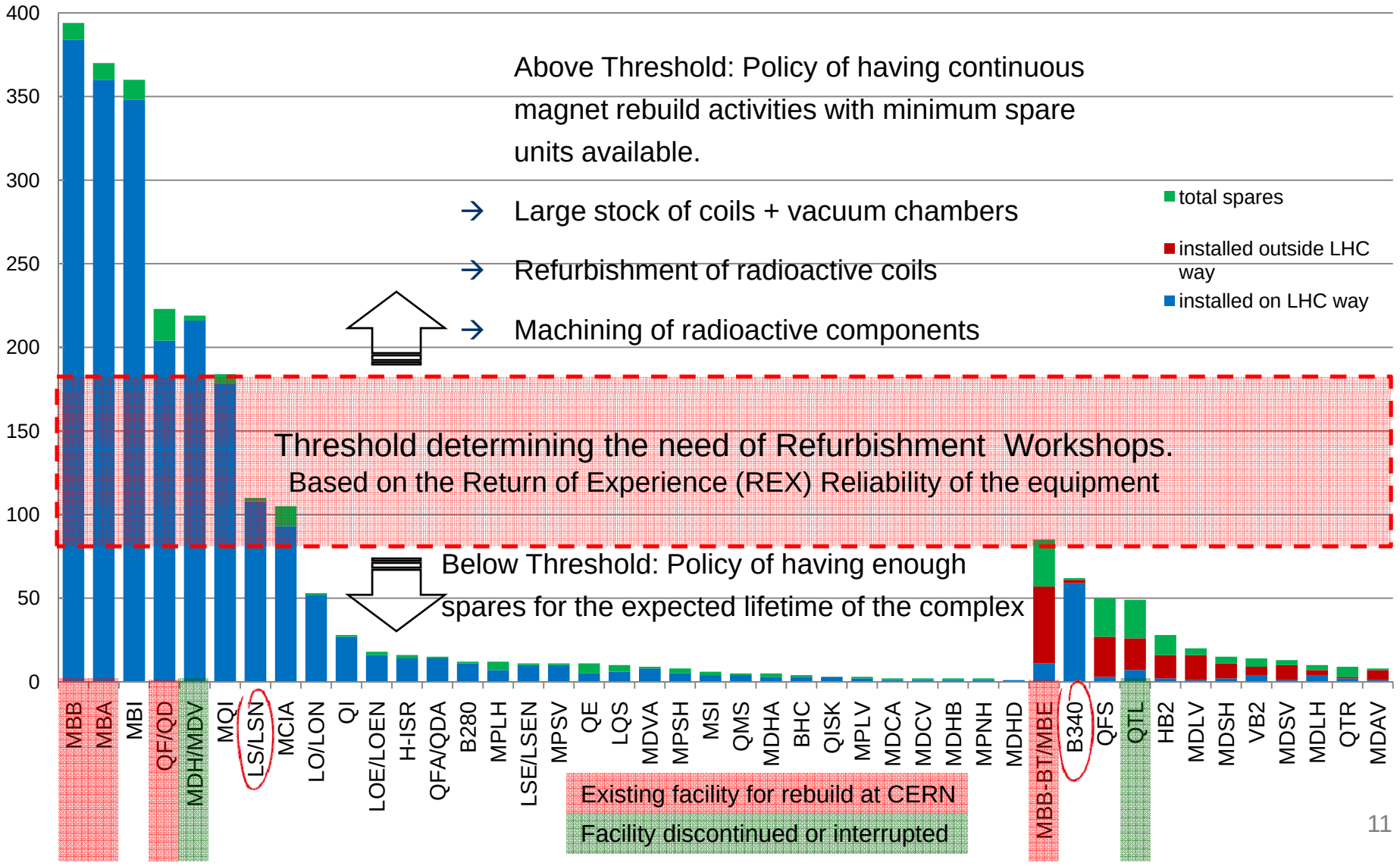
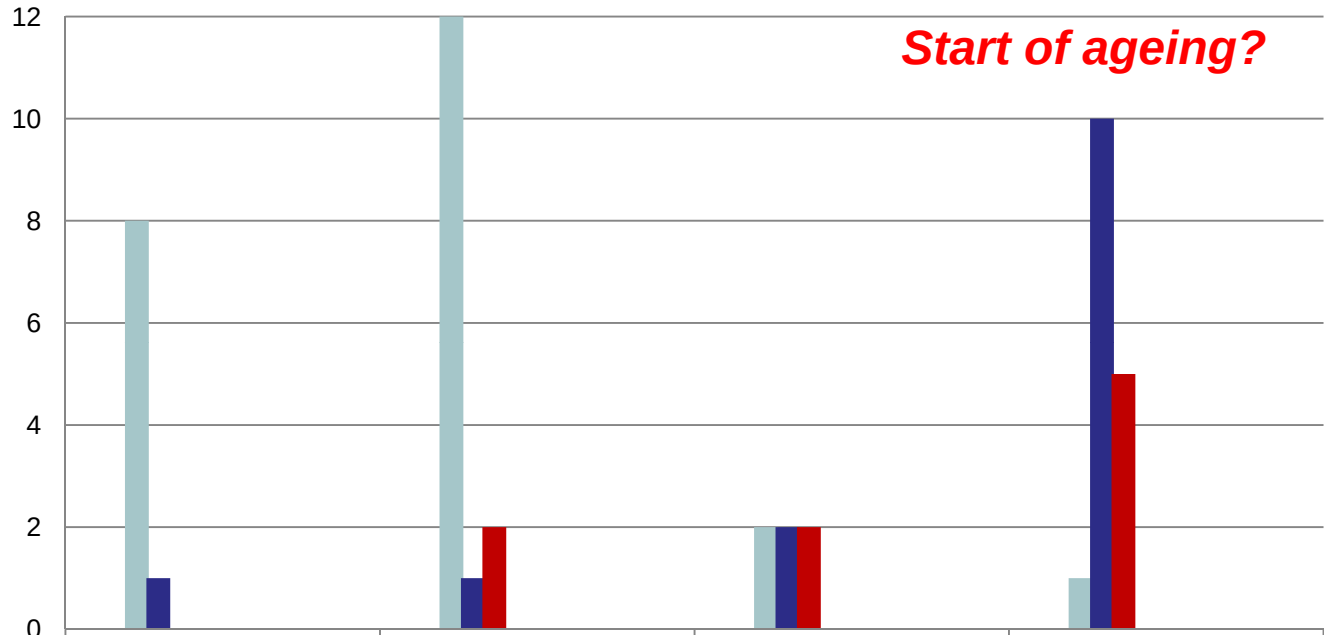


Spare Policy



REX Reliability of the SPS Dipoles (II)

SPS Main Dipoles (MBA&MBB) Evolution of Breakdowns



	1988-1992	1993-1997	1998-2002	2003-2007
vacuum leak	8	12	2	1
Water leak	1	1	2	10
Short	0	2	2	5
Beam induced damages	0	3	3	0
diverse	2	1	2	0
Exchange for PPS project, VC shifted, impossible to install RF shielding	0	0	13	0
Preventive exchange	7	27	15	6
no information available	4	0	0	0
total	22	46	39	22

MTTR: Interpretation & Objectives

M - T - T - R

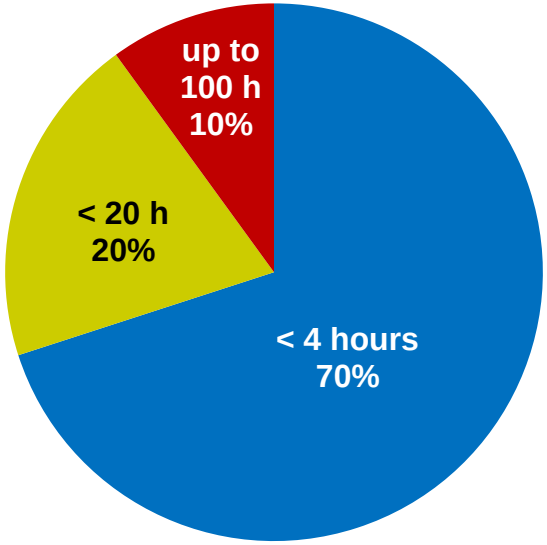
Minimum	Time To	Repair
Maximum		Recovery
Mean		Respond
		Replace

MTTR (Repair)	MTTR (Replace)
4 hours	20 hours
•Magnet Cooling Faults •Leaks •Water Pressure Faults • Overheating •Magnet Interlock Faults •Specific Electronic Faults •Imbalance current detector •Null Field Probes	Magnet Exchange Note: Specific issues for the MTTR (Mean Time to Respond): although the acknowledgement of the fault is usually very quick, the initiation of the mitigation can be postponed due to various reasons: -AB/OP (Physics priority) -SC/RP (Safety) - « Trivial »matters (nights, week-ends)

MTTR: Return of Experience

- Breakdowns in SPS Complex :
  - 2006: 35 interventions (27 in Target & North Areas), 4 magnets exchanged
  - 2007: 26 interventions (13 in Target & North Areas), 5 magnets exchanged
  - Objectives: remain below actual statistics (hereunder)

Distribution of MTTR according to 2007 breakdown Log (26 interventions)



Discussion

- Sufficient spare coils for SPS main magnets exist for the next 4 to 5 years (at the present rate of breakdown)
- Other potential risks on the SPS magnet system:
  - Main busbars
  - Water-cooled cables (TS-EL)
  - Installation vehicles (TS-IC)

$\Rightarrow$ *adopt coherent maintenance/spare policy*

Status and outlook of B-train systems for magnetic field control

M Buzio, R Chritin, D Cornuet, P Galbraith, D Giloteaux (AT/MEI)

Contents

Slide 16

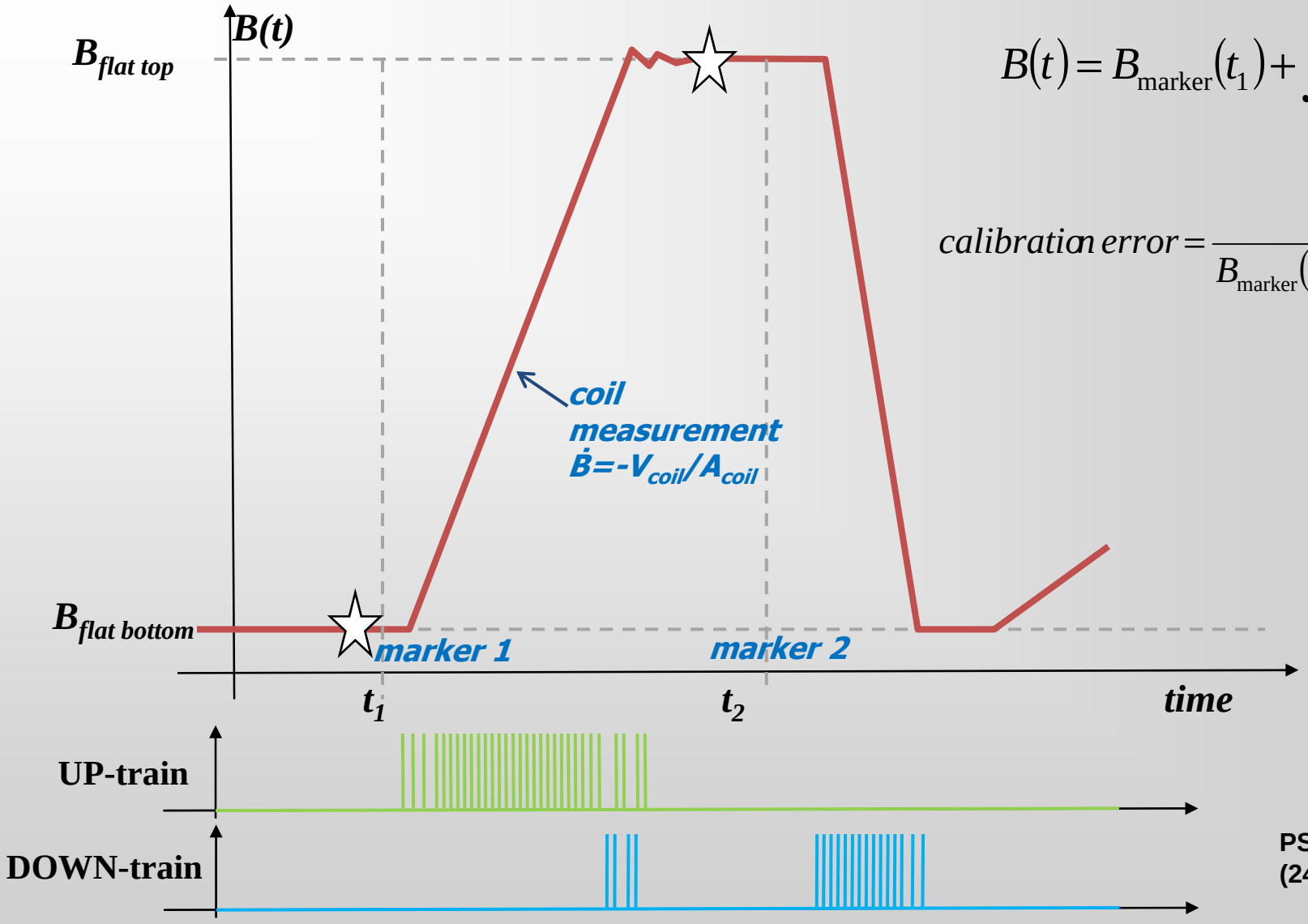
MB2

After a brief overview of the different B-train systems in use (Booster, PS, SPS, LEIR, AD) and their main features, the presentation is focused on reliability issues. Recent faults are reviewed, along with the corrective actions undertaken, and the risks for operations in 2008 are estimated in terms of lost beam time. In particular, the present and future availability of spare instrumentation, acquisition and interface components is addressed. The procedures established to switch rapidly onto redundant or synthetic B-trains are then recalled, together with the agreed attribution of responsibilities for what concerns first-line (piquet) and repair interventions. To conclude, some planned improvements to performance and reliability such as modernization and uniformization of electronics, new magnetic sensors and enhanced remote diagnostics are discussed.

Main risks and impacts of system
Mitigation measures
MTTR
Spares policy
Level and organization of service (piquet)

Marco Buzio, 1/21/2008

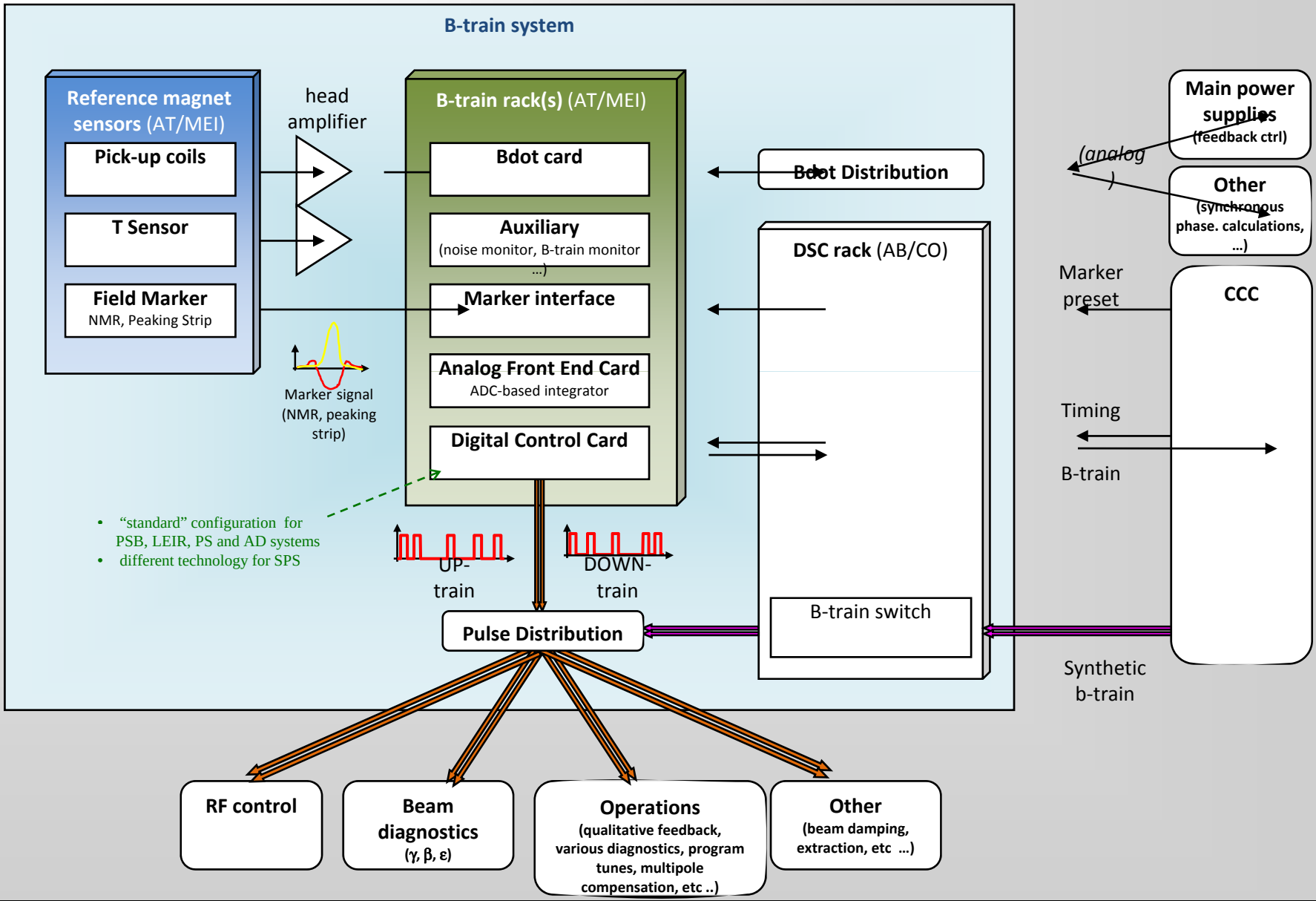
Principle of B(t) measurement



$$B(t) = B_{\text{marker}}(t_1) + \int_{t_1}^{t} \dot{B}dt$$

$$\text{calibration error} = \frac{\int_{t_1}^{t_2} \dot{B}dt}{B_{\text{marker}}(t_2) - B_{\text{marker}}(t_1)} - 1$$

B-train systems: simplified generic block diagram



3. B-train maintenance policy

- **Responsabilities:** as of 2006, **AT/MEI** (former AT/MTM) is fully responsible for the maintenance and upgrades of the measured B-trains.

- **Standard maintenance:** carried out routinely during shutdowns
- systematic calibration campaigns
- minor upgrades , e.g. new peaking strip signal outputs for OASIS, LCD field display, refurbishment of cabling ...

- **In case of problems:**

- Call AT/MEI expert's "first line": R. Chritin, D. Giloteaux or P. Galbraith
  NB: the service is based on "best effort" and is NOT a piquet
- if the problem is not solved rapidly, operation is switched on the reserve B-train
  (typical time required: of the order of minutes for measured B-train)
- diagnostic and repair interventions proceed usually in parallel with operation
  (typical time required: a few hours to a few days)

Transfer of "switching duties" to AB/OP and AB/RF piquet teams: discussed in the past, documentation produced, little or no opportunity to put it in execution during 2007

experience shows that most problems appear during commissioning and restart
complex, strongly coupled system (feedback loops) ⇒ diagnose in actual working conditions

Main goal:

- ensure that existing systems keep working, in their current conditions, until the end of the lifetime of each machine *(10 years for PSB ? 30 years for SPS ??)*

  To be kept in mind: systems will get older and more fault-prone; staff will get older and retire ...

Additional objectives:

- reduce downtime: improve reliability of components, facilitate maintenance, calibration and repairs
- improve existing systems, if required:
  · add new functionality (e.g. more diagnostics, easier switching between trains, put in operation existing but disused components, etc ...)
  · enhance accuracy and resolution
- design and implement new systems (AD/ELENA)

5. Conclusions

- All **existing B-train systems** are in acceptable working order, with low expected downtime, and no immediate concerns.
- The **strategy to mitigate** the effects of faults, i.e. switching onto redundant acquisition chains while carrying out repairs is well tested ⇒ very little lost machine time

however

- The **general availability of spares** is uncomfortably low considering the long-term
- The measured B-trains of PS and SPS have a critical importance (no operation with simulated train) yet are potentially vulnerable:

  PS: peaking strips (+ their powering) are irreplaceable today
  SPS: very few spares (nonstandard cards, long coils), difficult to replace

- **Proposed actions**:
  - ❑ Consolidation of documentation, to prevent the dissipation of crucial know-how
  - ❑ Standardization and modernization of electronics for existing and future systems, to ensure long-term survival of the systems and improve the availability of the machines
  - ❑ Assess the feasibility of Peaking Strip and pick-up coil replacements
  - ❑ According to needs and demands from AB, evaluate possible implementation of functional improvements

Discussion

- In the long run, could one do only with (improved) « synthetic B-trains »?

Accelerator Technical & Operation Review (ATC/ABOC Days)
Session 4: MTTR & spare policy for the LHC injectors & experimental areas

Vacuum System of the LHC Injectors and Beam Transfer Lines

J.M. Jimenez

Reliability of the vacuum systems (1/5)

- **Vacuum systems failures result from:**
  - Leaks induced by:
    - Mechanical fatigue e.g. welded bellows and welded SPS dipole chambers
    - Thermal fatigue induced by beam losses e.g. transition pieces
    - Corrosion of vacuum components like bellows and feed through resulting from the combination of humidity and radiations (SPS North Area TDC2, SPS TWC cavities, PS Booster feed through)
    - Beam impacts onto the vacuum chambers, bellows, transition pieces, etc.
  - Radiation induced damages to:
    - The sector valves switches and pneumatic
    - The ion pumps and gauge cables and connectors
  - Failure of the vacuum instrumentation e.g. gauges and their controllers

Reliability of the vacuum systems (4/5)
Mitigation measures

- **Vacuum components**
  - ☞ Leaking components or connection can be varnished if the leak is accessible and smaller than 10^{-6} mbar.l/s
  - ☞ Bigger leaks or inaccessible leaks requires the exchange of the leaking component or seal
  - ☞ Differential pumping could be an option… implemented in 2007 in LINAC 2
- **Sector valve**
  - ☞ If the switches which provide the valve status or if the pneumatics are damaged by radiations, then, the valve will be opened and disconnected from both Control & compressed air to avoid any closure until the next access (min. 4 hours required)
    ⇨ Implications to the machine protection has to be accessed
- **Instrumentation**
  - ☞ Instrumentation controller or cards can be easily exchanged
- **Controls & Monitoring**
  - ☞ Not required for the operation… can be fixed without impacting the operation
  - ☞ Spare LINUX server is available in case the WINDOWS servers crash…
  - ☞ 4 VAC-ICM Staff can intervene on PLC chassis

Spare policy for all accelerators (1/2)

- **Vacuum components except sector valves**
  - ☞ Impossible to have spares for all vacuum chambers, transition pieces and bellows ready to be used due to the large variety of components ⇨ Storage and cost problem !
  - – Basic components like tubes, shaped tubes, flanges (except enamel flanges), bellows are available ⇨ LEIR case shall be worked out e.g. bellows and DFH chamber
  - ☞ If a vacuum component is found to be leaking, then, a new component has to be manufactured by assembling the basic components together, vacuum cleaned and leak detected before becoming available…
  - ☞ Availability of transfer line windows is not known ⇨ action with AB-ATB
  - – Already planed corrective actions
    - Manufacture additional spare chambers e.g. MBN type for the SPS North Area
    - Design & manufacture new transfer line windows
- **Pumps**
  - – Ion & sublimation pumps are available for all types

Spare policy for all accelerators (2/2)

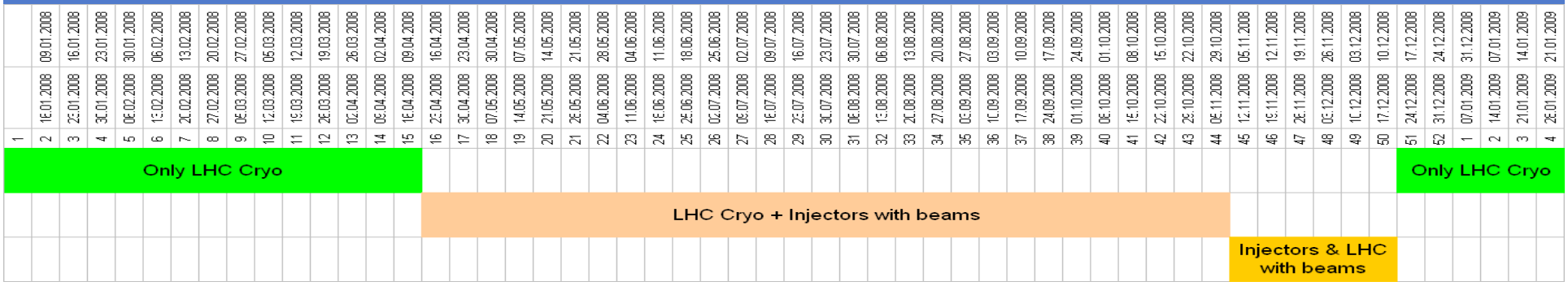
- **Sector valves**
  - ☞Spare sector valves are available
  - ☞ Spare parts are available for all types of sector valves to allow in situ repair of switches and pneumatics
- **Instrumentation, Controls & Monitoring**
  - ☞Spares are available for all machines
    - New spare for the new type of controls (PLC based) ⇨ 3 spare PLC masters are available
    - Recuperated racks for the old fashion controls (PS, PS Booster & AD machines)
    - Sector valve racks: 2 by machine
    - Ion pump power supplies: 10 by machine (compatible SPS/LHC)
    - Gauges & controllers: all types are available ⇨ shared between machines
  - ⇨ISOLDE instrumentation need to be replaced by a more recent one

Vacuum Piquet Service (1/2)

- **New CERN-Wide Accelerator Piquet Service**
  - ☞ Vacuum Piquet Service changes to take into LHC operation constraints: longer run (limit of 9 weeks for stand-by), optimisation of resources, need of an expert support and technical opportunity for Staff
- ☞ **Vacuum Group will provide two types of support to operation:**
  - Piquet Service
    - 2 staffs on stand-by in order to be able to access underground areas
    - Duty: After being called by the CCC, analyse the cause of the incident and try to fix it using the remote access on control system or directly on the hardware in the surface building or in the tunnel.

      In case of difficulties to fix the problem or if a risk to the person or to the material has been identified, the staff on stand-by can call the Experts for advise.
  - Expert support ("Piquet libre", not on stand-by !)
    - A list of Experts by systems is accessible to the staff on stand-by
    - Help expected: After being called by the staff on stand-by (we shall avoid the direct call from the CCC), the Expert will give advise to the stand-by team and will intervene on site if required to fix the problem. If the problem can not be fixed, he will report to the CCC.

In case of a major mains cuts, priorities will have to be defined !



MTTR
Failures classified by increasing beam downtime

- **Sector valve problem**
  - Undefined position or valve is closed and can not be opened
    - Control can access the valve:
      - YES: less than 1h
      - NO: ~2 h
    + Pneumatic or switch problem ⇨ need to access the valve in the tunnel: 2-3 h
- **Vacuum instrumentation failure**
  - Valve can not be opened due to a gauge problem: 1-2 h
- **Mains cut**
  - IT infrastructure is available (Profibus, Ethernet, servers…):
    - YES: < 3 h
    - NO: 3-5 h
  - ☞ Vacuum pumps and instrumentation have to be restarted manually, one-by-one !
  - ☞ Old electronics suffer from the cuts (even short cuts) ⇨ The amount of failures is always the “cerise sur le gateau”…!
- **Leak on vacuum or machine (beam instrumentation, magnet, etc.) components**
  - Leak can be varnished (localization included): 3-4 h
  - Leak can not be varnished, spare component is available:
    - YES: Max. 8h
    - NO: 2-3 days to manufacture a new vacuum component

Conclusions

- **Apart from the transfer line vacuum windows which availability and responsibility has to be followed up actively, all spare components or subcomponents are available**
- **Unique Piquet service will have to gain experience**
  ⇨ no impact is expected on the accelerator operation
- **Consolidation of PS and PS Booster has to continue to standardise the vacuum controls & monitoring tools**
- **Other consolidations will be proposed for evaluation e.g. heating of feed through in SPS**

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ATC-ABCO Days

Session 4 - MTTR & Spare Policy for the LHC injectors & experimental areas: AT & IT Groups

Databases, Networks, Informatics
22 January 2008

Tim Smith, Frédéric Hemmer

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Switzerland
www.cern.ch/it

Computer Centre Operations

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- 24x365 Operator on shift
  - Performs simple documented interventions
- 24x365 System Administration Coverage
  - Most of IT servers, incl. Linux DB servers
  - First line diagnosis & intervention
  - Answer within minutes; on site < 1 hour
  - Unyielding problems are forwarded to experts
- Experts on best effort coverage
  - Usually complex services
  - Most services do not have enough people to provide a piquet service

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Communication services (II)

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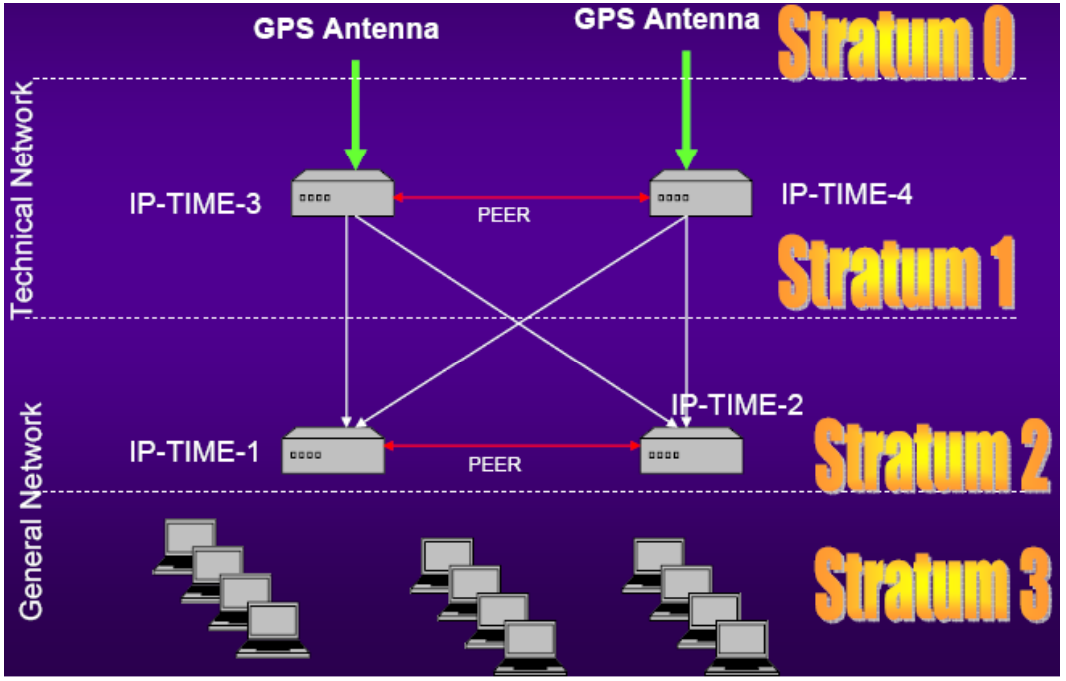
- Networking *Services*
  - DNS, DHCP, NTP, RADIUS
  - Redundant configurations
    - Best effort support outside worki



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Communication services (III)

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- Telephony Services
  - Redundant configurations
  - Maintenance contract 24x365 for fixed and mobile telephony (NextiraOne/Sunrise)
    - Max. 1hr intervention time outside working hours
  - The fixed telephone network has 3 hours of power autonomy
    - Local UPS (+ diesel backup...)
  - The GSM network is not covered by UPS

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Database Services

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- Most recent DB services have higher redundancy
  - Linux with Oracle RAC
  - Storage with high availability features
  - Basic Server Administration using Computer Center Operation Services
  - Complex problems need experts to intervene
    - Best effort coverage
    - Most experts > Eb hence no compensation possible
- Some Databases are still running on legacy ageing Sun/Solaris
  - Planned to be upgraded to Linux/RAC in 1H08

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Issues (as perceived from IT)

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- Need list of IT services critical for accelerator operations
  - The experiments have such a list including
    - Criticality; Responsible
    - Maximum allowed down time
    - Impact on the experiment
  - See https://twiki.cern.ch/twiki/bin/view/CMS/SWIntCMSServices
  - Implementation must take account of global resource envelope
- Interdependence Tests should be made by switching off IT services (or access to them);
  - Reliable services hide possible failure modes
- Databases need to be regularly updated with the quarterly Oracle security patch and relevant OS patches
- LHC “logging” database seems to be critical
  - Maybe could consider hardening applications by caching data?

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Issues (as perceived from IT) - II

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- Providing coverage better than “best effort” for IT services is problematic
  - Modern services are complex
  - Complicated end-to end problems require experts
  - Most services do not have the minimal number of experts required for standby services
  - People will not be willing to enroll to standby services if they are not compensated appropriately
    - Most of the experts are > Eb
    - IT services run the whole year
    - This problem has been highlighted for the last 7 years

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Issues (as perceived from IT) - III

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- How to effectively communicate notice of service changes or interruptions
  - TS use *notes du coupure*
    - Printed and posted to entrance doors
  - IT use pop-up alerts targeted to impacted community
    - Coordinated through a *Service Status Board*
  - Which communities need to know about which changes / interruptions?
    - Returns to the criticality / dependency issue

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CNIC Security Issues

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- CNIC policy and implementation documents updated
  - Non-implementation leaves serious risks… *However*
    - Currently impossible because of commissioning
    - Then will be impossible because of operations
    - Then will be impossible because of machine development …

      This is living dangerously!

- Technical Network security is compromised by the significant number of “trusted” hosts
  - Especially important are desktop Development PCs
- TN Intrusion Detection System should be implemented
- Security of Controls PCs should be assessed/improved
- Reorganize connectivity of controls devices
- Regular security scans must be scheduled on the TN
- Review and reduce number of service accounts…

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Summary

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- IT Services are critical to accelerator operations
  - As illustrated in recent incidents
- Interdependencies are either unknown or undocumented
  - A list of critical services should be established
  - Tests should be performed to expose the dependencies
- 24x365 coverage applies to first line interventions only
  - Complex problems require experts who are only available on a best effort basis
- There are significant security risks with devices connected to the technical network
  - CNIC policy should be implemented
  - Regular scans and updates are necessary

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Discussion

- Suggest to conduct risk analysis of IT services for accelerator operation, similar to what was done for other technical equipment
- Although interfering with operations, scans and updates of the TN are necessary and should therefore be programmed (just like AUG tests)
- General trend: redesign IT services to be redundant, to reduce need for piquet, and satisfy with « best effort »