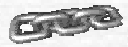
Controls Infrastructure

- Introduction
- Topics covered
- Changes & trends
- User needs
- Schedule, a word
- Conclusion

Introduction

RULE

LTI Controls  SPS Controls

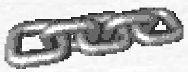
AND

SPS Controls  SPS Controls’ (SPS2001…..)

BUT…..

Introduction’

Exception, **confirming the rule**

For some EG
LTI controls  LHC Controls

Introduction"

CNGS Controls

Topics covered

- Applications (cf. veym & jonker)
- Alarms
- Middleware
- Timing
- Workstations
- Front Ends
- Network

Changes and trends

Alarms

- Scale still increasing
- Interfacing new systems (industrial…)
- Adapted internal architecture
- New reduction techniques

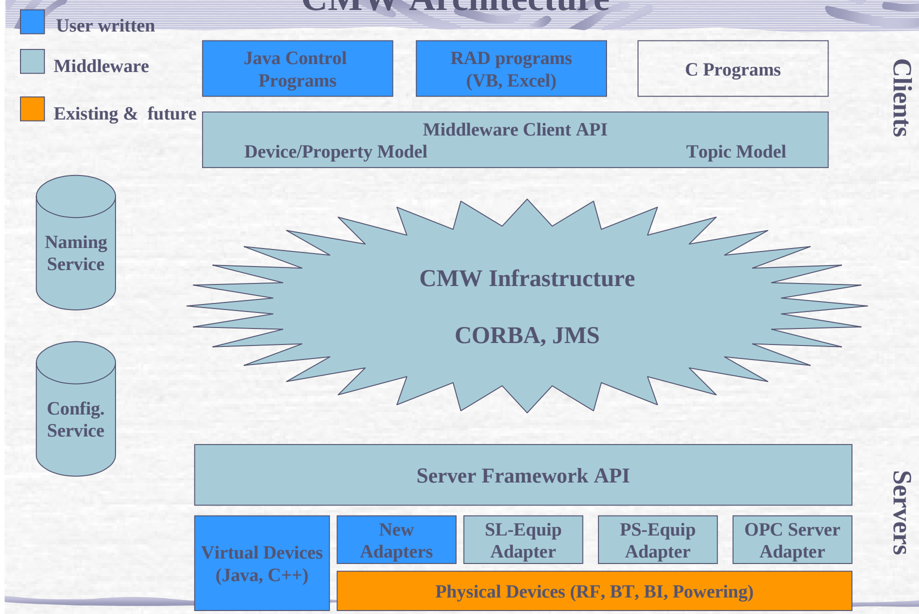
- Exploring new "platforms"

Changes and trends

Middleware

- Replace SL-EQUIP & RPC
- Build on Device/Property model
- Provide get/set, publish/subscribe
- Incorporate slow timing semantics
- Cover the existing platforms (OS, programming languages)
- ………

CMW Architecture



CMW current state

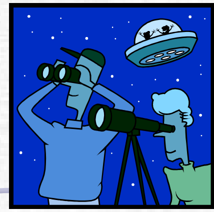
- The CMW project fulfills the demanded functionality
  - ✓ Supports device/property model
  - ✓ Supports publish/subscribe (device/property & topics)
  - ✓ Supports inter-object communication by installing CORBA & JMS infrastructure
  - ✓ Supports integration of industrial devices (via OPC)
  - ✓ Supports access to existing SL and PS devices
- First version available, will be used in operation for CESAR and "Excel passerelle"
- Consolidation before startup 2002
  - Access control, administration tools, logging, generic browser
  - C client API
  - Performance improvements

Changes and trends

Timing (stable, ever needed functionality)

- Centralized, fibber based distribution system optimising signal latencies (mtg, pre-pulse, revolution frequency)
- Quest for new interfaces :
  - G64_TX4, G64_IRIG-B…..

GPS



Changes and trends

Workstations

- PC's start taking over X-terms, architectural split between GUIs and "business" layer
- Select server architecture for the "business" layer
- Thou shall program in JAVA

Changes and trends

- Front End
  - Users use PLCs sometimes with SCADA for cycle independent slow controls
  - ! (Users expect VME we provide CPCI)
    - Cost, OS support, interfaces (Ex:GigaSamplers)
  - Remote reboot/terminals
  - MIL1553 saga continues
  - WorldFIP, Bus Arbiter gateway
  - Real time

Changes and trends

Network (Slide 13)

- "Accelerator network" becomes a collection of building networks
- The user shall not perturb the network
- *If the network is sick take "Remedy" before seeing a doctor*
- SL/CO will do their best to negotiate everything that is negotiable (special attention to intervention times)

User needs(?)

- PCR (cf. veym, jonker, lamont)
- VAC & MS
  - Alarm
  - Logging
  - SCADA interfacing (Middleware)
  - PLC interfacing SOFNET-S7 (?)
  - PLC system date synchronization

User needs

- PO
  - Timing (MTG), alarms, middleware
  - FEC running ROCS with RR & RT
    - 4-6 LTI
    - 2 CNGS

User needs

- BI
  - LHC Beam Description (Telegram ?)
  - Timing (MTG, Prepulse, Rev.), alarms, middleware
  - FEC, RR & RT (LHC type)
    - 30
  - WorldFIP 31.25Kbps gateway

User needs

- BT
  - Timing (MTG, Prepulse, Rev.), alarms, middleware (?)
  - FEC, with RR & RT
    - 4 (FYI 80-100 PLCs)
    - Specific drivers support
  - Siemens SOFNET-S7 protocol long term support, PLC integration interface

Schedule

- Infrastructure in place 6 months before first test beam
- Stable APIs 1 year before test beam

Conclusion

- The required LTI/CNGS controls infrastructure to be provided by SL/CO follows mostly the SPS infrastructure under upgrade
- The foreseen evolution of the SPS controls infrastructure should be stabilized by Q3 2002(?) and available 6 months later
- Some specific LHC control items must be delivered on the same dates

LTI and CNGS Controls Review

Application Software Aspects

Contents

LTI Controls Requirements (1/4)

- What's different ?
  - Higher risks
    - Fast SPS extraction of high intensity beam
      (nominal batch 2.67*10E13 p @ 450 Gev)
    - Destructive beam power (1.9 MJ @ nominal batch)
  - High precision
    - SPS extraction and energy
    - Small aperture (~20mm for MBI)
    - LHC Injection precision of 1.5σ
    - Small transverse emittance budget (3.4 μm rad)
      - Requires Good optical matching between SPS and LHC to reduce LHC injection oscillations

LTI Controls Requirements (1/4)

- What's different ?
  - Good protection
    - Of the equipment in the transfer lines
    - Against misinjected beam (LHC magnet quench)
  - High operation efficiency
    - Fast and efficient "switching" between SPS operating modes

LTI Controls Requirements (2/4)

- **Functional Requirements (V.Mertens, Chamonix'99 & LHC COOP Forum)**
  - Line Steering
    - Measure & change (trim)
      - Settings, trajectories
    - Minimize excursions
    - Store/Load "golden trajectories"
    - Track drifts due to temperature, power converters
  - Betatron and dispersion matching
    - Change SPS energy and measure trajectory
    - Read and write from/to MAD
    - Change, store and load settings
  - LHC Injection Steering
    - Measure and track LHC orbit + oscillations
    - Change injection element settings, adjust TDI and collimators positions

LTI Controls Requirements (3/4)

- **Functional Requirements**
  - "Sequencing"
    - Move in TDI + collimators, send pilot pulses, measure and adjust, inject full batch, retract TDI + collimators, etc …
  - Surveillance
    - Vital Data : injection kicker, dump system, power supplies
    - Monitor technical services : vacuum, temperature
  - Interlocks
    - Disable SPS extraction and dump beam in SPS or
    - Don't fire injection kicker and put beam on TDI (injection inhibit)
  - Post-Mortem (record + faults)
    - Power supplies
    - Kicker data (timing, pulse)
    - BI data (intensities, losses)
    - Injection data (profiles, bunch positions)

LTI Controls Requirements (3/4)

- **Operational Requirements (G.Arduini, K.Cornelis)**
  - Control ALL transfer lines from the SPS
  - Use the SAME software for all transfer lines
  - Protection against bad manipulations
  - Good diagnostic and debugging tools, especially in the light of the future SPS multi cycling operating environment (interlocks !)
  - Smooth and well defined transition between the current and future software solutions

Application Software (1/3)

- **TZ : current status and possible enhancements** (input from V.Paris and F.Chevrier)
  - Stable and fully supported software suite allowing :
    - Settings measurements (TZ measure)
    - Settings changes (TZ Drive)
    - Automatic steering (TZ Steering)
  - No intrinsic multi-cycling features
    - Beam In and Out segments matching recalculated and sent to hardware at each super cycle change
  - Possible improvements for faster super cycle changes
    - Preload several sequences into Hardware
    - Speed-up BIS/BOS matching
    - Get rid of polarity switch and acquisition delays handling

Application Software (1/3)

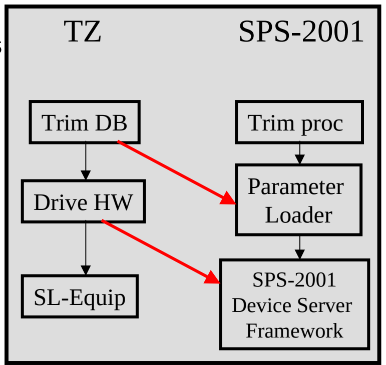
- **TZ : current status and possible enhancements** (input from V.Paris and F.Chevrier)
  - Security improvements
    - Sanity checks to avoid mistyped trims
  - Possible Integration of new BI equipment through additional black boxes

Application Software (2/3)

- **SPS-2001: current status and perspectives**
  - Provide control facilities to operate the SPS in multi-cycling mode (fast changes of super cycle)
    - Cycles management (equipment loading, trims, …)
    - Management of equipment groups (I.e. LHC Extraction ON/OFF)
    - Publish/subscribe for "real time" view of the machine
    - New software interlock management (replacement of SSIS)
  - Aimed at providing homogeneous software approach for the control of the SPS ring and transfer lines
    - Includes control of all power converters and kickers
  - First prototype currently used in PCR for state and settings control of the SPS proton injection kicker

Application Software (3/3)

- SPS-2001
  - Deliverables and deployment
    - Planning proposal in preparation by steering committee and project team (covering 2001 … Spring 2005)
      - Specifies PCR deliverables
      - Proposes transition path with "Wilkie" and TZ software



Areas for Decision

- How far do we invest/improve the TZ software ?
  - TZ could, with some modifications, do the job for 2003 and for the sector test in 2004 but has limitations in the light of the future SPS multi-cycling operating modes
- SPS-2001 planning and objectives require :
  - Approval at SL/TC level (several groups concerned : SL/BT, SL/PO, SL/BI, SL/OP, …)
  - Definition of technical work packages (I.e. bridges between existing TZ modules and new SPS-2001 modules) and resources (re)allocation
  - Rigorous validation scheme (fall 2003 for TI8)
- Clear decision and strategy required this year !

Conclusions and Milestones

- Beam Transfer equipment and software interlocks will be handled by SPS-2001
- SL/BI and SL/BT need software interfaces to the control system for March 2002
- Early 2003 : check SPS extraction (TT40)
  - Temporary application software acceptable
- Fall 2003 : TI8 commissioning
  - All basic software functionality NEEDED
    - Line steering, optical matching, sequencing, surveillance, interlocks
  - Application software should be as close as possible to its final design for the sector test
- April 2004 : LHC sector test

SPS Extraction (15')

Michel Jonker

Review of LTI and CNGS Controls
Tuesday, July 10th 2001, 08:45
SPS Auditorium

- Goal:
  - Identify the systems that will be needed to control LTI and CNGS equipment
  - Examine the interfaces between these systems and the SPS and LHC accelerator controls
  - Identify areas where new initiatives are required
  - Clarify controls responsibilities and milestones at all levels
- In this talk:
  - Focused on the extraction test in 2003 (I.E. LSS4)

2003 Extraction Test in LSS4

What do we want to control

- Extract beam from the SPS into the first part of TT40:
  - pilot beam

  possibly up to (depending on hw availability)
  - full intensity LHC beam
  - ~~full intensity CNGS beam~~

  (I.e. need good interlock system)

2003 Extraction Test in LSS4

- What is there to operate
  - Magnets
  - Kickers
  - Septa
  - TED
  - Beam Instrumentation
  - Interlocks

Magnets

12 new rocks/mugef channels

- 4(H) + 4(V) bumper magnets in the SPS
- MBHC (chain of 3 elements, 15 mrad total deflection)
- MBHA (chain of 4 elements, 15 mrad total deflection)
- 3 quads QTMD, QTLF, QTLD
- 3 correctors (2xV, 1xH)

- Control like other rock/mugef (will be SPS2001 compliant)
- Bumper magnets in SPS and dipole chains in TT40 are interlock sources (beam dump and/or extraction veto)

Kickers

MKE: 5 elements (up to 0.6 mrad total kick)

- 5 pfn's (beware of erratics!)
- 1 HT generator per extraction
  - Two (3?) Extractions in case of CNGS timing: 1.1 μs rise & fall time (50 ms apart)
  - One extraction for LHC
- Control like other kickers (SPS2001 compliant)
- Protection (extraction inhibit):
  - Compare the HT on the 5 PFN's just before the extraction with an independent reference based on MBI DCCT
- Extraction inhibit also available to external sources (dr. Interlock)

Septa

1 TPS: graphite diluter (passive protection element)

6 MSE: active elements (12 mrad total kick)

- Girder position settings and measurement
- Slow-control measurement and survey:
  - Cooling (temperature, flow, pressure)
- 6 rocks/mugef channels
- Device Server provided by BT (SPS2001 compliant)
- Interlock source (current, position, cooling)

Beam Instrumentation

- 1 fast BCT
  - Independent measurement of 72 LHC bunches
  - Integrated measurement for CNGS extraction
- 5 BPM's
  - 1 large aperture (LSS4) to measure bumped beam position
  - 4 (TT40) x2 independent channels for LHC and CNGS beams
- 5 profile monitors: 2 (LSS4) + 3 (TT40)
  - Set-up
  - Measurement of beam emmitance
  - Validate position on TED
- 13 beam loss monitors 7 (LSS4) + 6 (TT40)

Beam Instrumentation

Controlled by biscotos … (SPS2001 compliant … ?)

- Important for 2003 tests: all BPM (SPS, TZ) to be accessible by similar mechanism.
  (SPS2001 compliant by end 2002)

Interlocks

- Large aperture BPM, measured bumped beam position will feed the extraction interlock
- SPS beam loss monitors as input to HW interlock
- TT40 beam loss monitors into SSIS or Sps2001SIS
  - Possibility to inhibit next cycle if losses are excessive
- Profile screens: source of LHC injection interlock

Extraction Operational Control

Wish lists for 2003 tests

- MKP Verification of prepulse using naos
- All measurement readout with data per extraction (CNGS)
- Kicker and septa settings integrated into a coherent settings management and steering
- Trajectory correction for the extraction channel + TT40 available in 2003 (transfer matrices available)

Solution …?

apart from

- a few more black boxes
- a more sophisticated SSIS

the present SPS/TZ system could do the job

BUT …

- Will it do the job efficiently?

SPS2001 Project

The SPS2001 project has as a goal to provide a homogeneous beam control system in the PCR to operate the SPS and its transfer lines.

(and provides the potential to go beyond its targets)

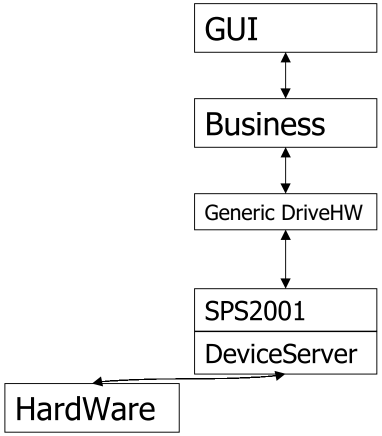
As such it will replace

- SPS ring control
- SPS orbit control
- TZ control

SPS2001 integration

SPS2001 products will be integrated gradually

old system new system



SPS2001 Project Planning

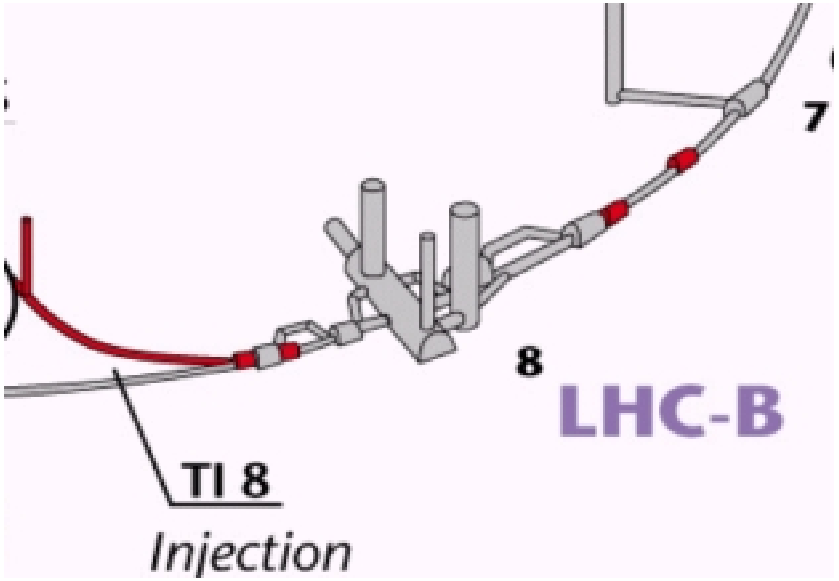
SPS2001 architecture and planning

based on first draft presented at the SPS2001 review meeting of July 4th.

To be used as a framework for further discussions within the SPS2001 project and with the external stake holders.

- We will match this with the specific requirements coming out of this meeting.

Injection



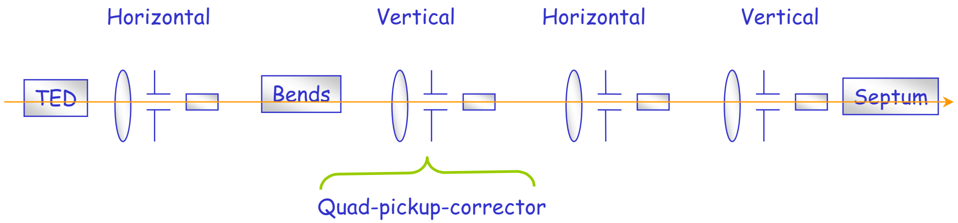
Injection

- **We going to have a lot to do at injection:**
  - **Establish circulating beam**
  - **Deal with multipoles**
    - Start tracking and correcting b1, b2 and b3 as persistent currents decay
    - To keep energy constant the horizontal orbit correctors will be driven a la BFS. to compensate b1 drift. (via a knob)
  - **Adjustment of TDI & injection collimators**
  - **Adjustment of cleaning insertion collimators**
  - **RF: Capture by 200 MHz, longitudinal feedback**
  - **RF: Transverse feedback**
  - **RF: Transfer from 200 to 400 MHz**
  - **Orbit, tune, chromaticity, energy etc...**

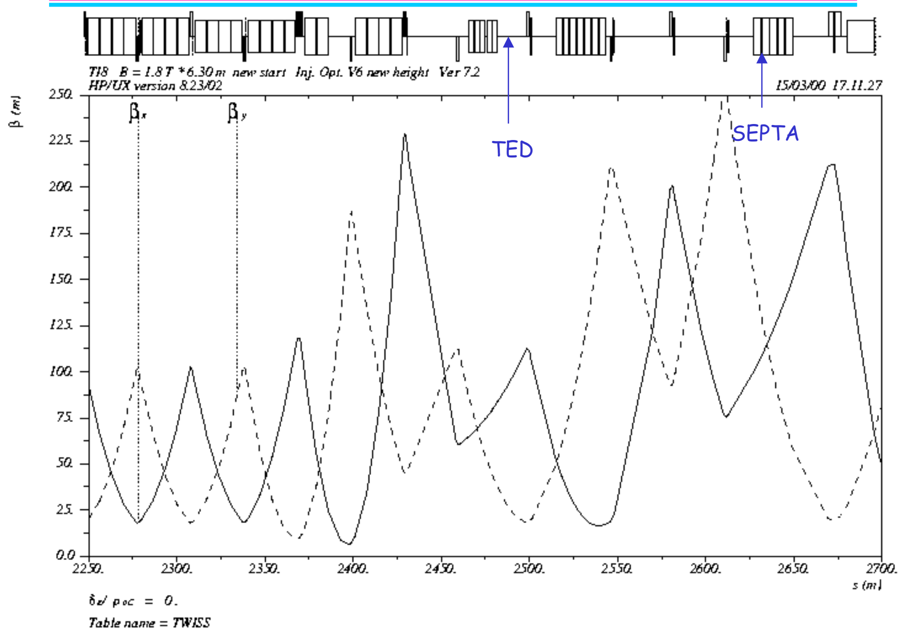
Concentrate here on actually getting beam safely into the ring

Last part of the lines

TED_87765	DUMP
MQIF_87800	QUAD
BPMIH	BPM
MCIAH	H ORBIT CORRECTOR
MBIAH*7	BENDS
MQID	QUAD
BPMIV	BPM
MCIAV	V ORBIT CORRECTOR
MQIF_87800	QUAD
BPMIH	BPM
MCIAH	H ORBIT CORRECTOR
MQID	QUAD
BPMIV	BPM
MCIAV	V ORBIT CORRECTOR
MSIB*3	SEPTA
MSIA*2	SEPTA



TI8



LHC

Ring 2

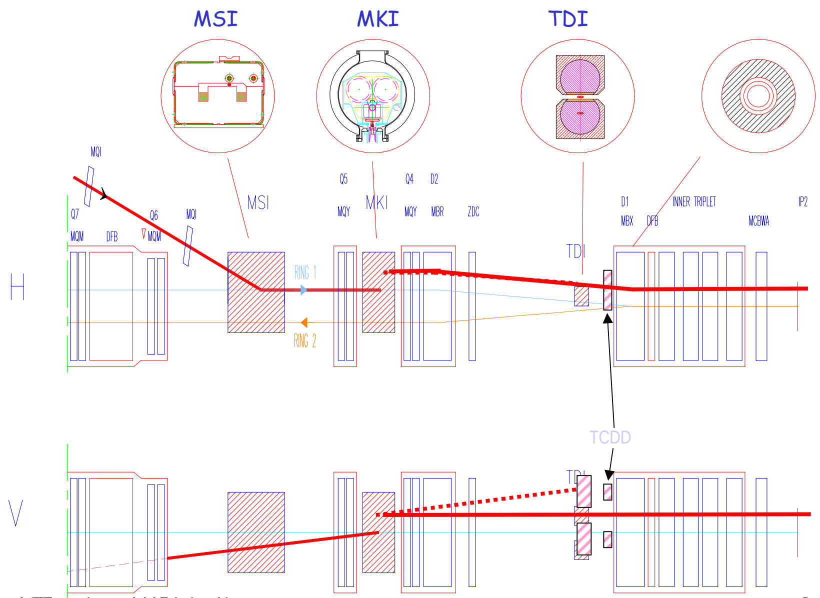
TCDD.4R8	TCDD - Cu Shield
TDI.4R8	TDI
MBRC.4R8.B2	D2
MCBYV.A4R8.B2	V ORBIT CORRECTOR
MCBYH.4R8.B2	H ORBIT CORRECTOR
MCBYV.B4R8.B2	V ORBIT CORRECTOR
MQY.A4R8.B2..1	Q4
MQY.A4R8.B2..2	Q4
MQY.B4R8.B2..1	Q4
MQY.B4R8.B2..2	Q4
BPMYB.4R8.B2	BPM
MKI.A5R8.B2	KICKER
MKI.B5R8.B2	KICKER
MKI.C5R8.B2	KICKER
MKI.D5R8.B2	KICKER
BPMYB.5R8.B2	BPM
MQY.A5R8.B2..1	Q5
MQY.A5R8.B2..2	Q5
MQY.B5R8.B2..1	Q5
MQY.B5R8.B2..2	Q5
MCBYH.A5R8.B2	H ORBIT CORRECTOR
MCBYH.B5R8.B2	H ORBIT CORRECTOR
MCBYV.5R8.B2	V ORBIT CORRECTOR
MSIA.A6R8.B2	SEPTUM
MSIA.B6R8.B2	SEPTUM
MSIB.A6R8.B2	SEPTUM
MSIB.B6R8.B2	SEPTUM
MSIB.C6R8.B2	SEPTUM

Common

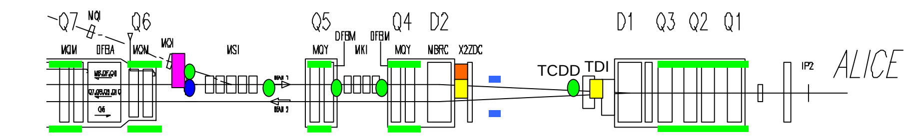
IP8	INTERACTION POINT
MP8	CENTRE OF UX85
MCBWB.1R8	SPECTROMETER COMPENSATION
BPMS.1R8.B1/B2	BPM
MQXA.1R8..1	Q1
MQXA.1R8..2	Q1
MQXA.1R8..3	Q1
MQXA.1R8..4	Q1
MQXB.A2R8..1	Q2
MQXB.A2R8..2	Q2
MQXB.A2R8..3	Q2
MQXB.A2R8..4	Q2
MQXB.B2R8..1	Q2
MQXB.B2R8..2	Q2
MQXB.B2R8..3	Q2
MQXB.B2R8..4	Q2
BPMS.2R8.B1/B2	BPM
MQXA.3R8..1	Q3
MQXA.3R8..2	Q3
MQXA.3R8..3	Q3
MQXA.3R8..4	Q3
MBX.4R8	D1

Injection

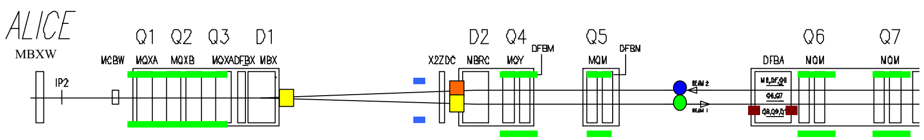
Volker Mertens



Instrumentation



BPM and BLM	BTPX	timing PU - 0.5 m	
Beam-beam rate monitors	BPMW	position PU - 0.5 m	
	BTV	first turn screen - 0.5 m	
	BTVI	screen for injection - 0.5 m	
	BCTI	beam current transformer 1 m	
	TCL	injection collimator - 1m	



Claude Fischer

Requirements

- **Energy**
  - **constant energy at SPS extraction**
  - **energy error needs to be measured on injected beam before capture. (50 MeV = 0.15 mm) ΔB/B < 10^{-4} over all injections**
- **Beam needs to be delivered to ±1.5 σ with respect to closed orbit of which ± 0.5 σ is for kicker ripple**
  - **I.e approximately ± 0.7 mm at the septa**
    - ⇒ exceptionally good orthogonal steering
- **Batch-to-batch stability**
  - **vital to prevent excessive injection oscillation**
- **Good matching - emittance preservation**
  - **a science in itself**
  - **run to run stability will be key**

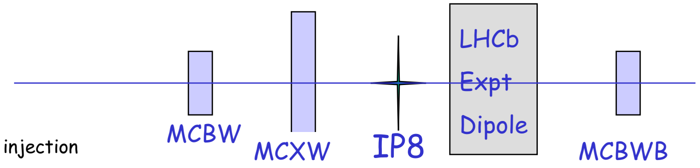
Requirements: TDI

- **Requires an orbit control within 0.5 sigma of the beam size at the TDI (-> 0.2mm).**
- **The TDI must be accurately aligned to the vertical crossing angle orbit.**
  - **For the current crossing angle separation scheme (Version 6 of the LHC lattice) the vertical orbit changes by 0.2mm over the length of the TDI which is of the same magnitude as the required alignment accuracy.**

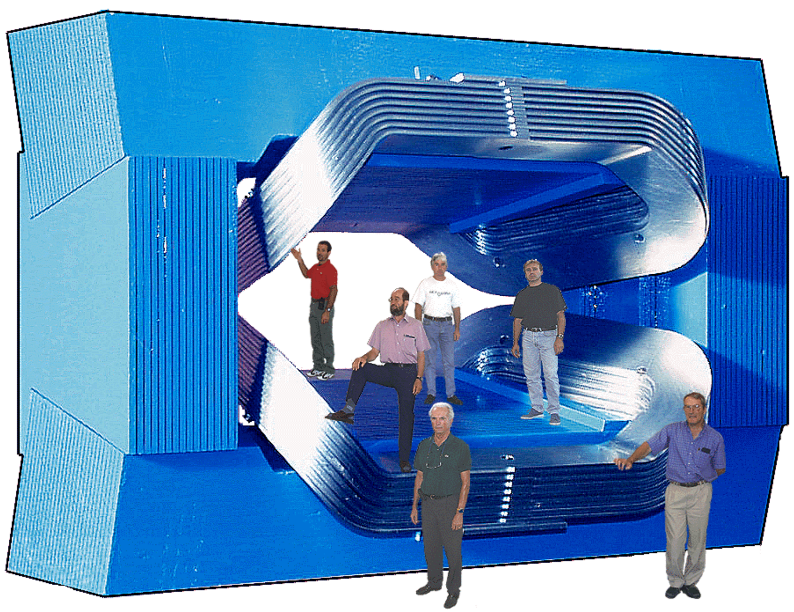
(5m long 200 kg each, precision: 0.1 mm ≈ 0.2 σ). 2 independent step motors

Requirements: Orbit

- **Separation at IP: orbit bumps**
- **Separation at parasitic crossings: crossing angle**
- **Compensation of spectrometer magnets**
  - **ALICE**
    - spectrometer magnet off at injection
    - IP2: vertical crossing angle ± 210 μrad
    - Possible need for orbit offset at MKI - additional 3 bump
    - Horizontal parallel separation bump
  - **LHCb**
    - spectrometer magnet on & it can change polarity
    - compensation produces large crossing angle in horizontal plane, combine with horizontal crossing angle bump
    - parallel vertical separation bump

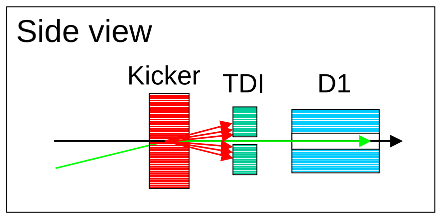


LHCb magnet



Pilot I

- **Issue injection request: RF, kickers, BI**
- **Retract TED at end of TI 8, move in TDI and send pilot pulse(s) onto TDI (kickers off), tune remaining part of line.**
- **TDI out**
- **Take PILOT into BLUE (or YELLOW) ring**



Pilot II

- If beam doesn't circulate - go to → **Establish Circulating Beam**
- Measure & correct:
  - transverse injection oscillations, injection error, Inject & dump if necessary
  - momentum error, re-do if necessary.
  - RF damper performance
  - RF LFB performance
  - Q, Q',
  - separation at IPs, crossing angle, spectrometer compensation bump
  - closed orbit.
- Adjust TDI with respect to closed orbit
- Coarse adjustment of collimators with respect to closed orbit: injection and cleaning $\pm 8.5\ \sigma$

Injection collimators $\Delta\mu \approx 20°$ down stream with respect to to TDI, other side of the IP

Intermediate beam

Medium bunch intensity: any losses distributed

This mode makes use of increase sensitivity of BPMs with intensity and would allow:

- exploration of the aperture
- fine adjustment of TDI & optics check
- fine adjustment of collimators

and checking of other beam instrumentation such as BLMs

- Prerequisites:
  - collimators to coarse,
  - TDI in,
  - possibly some auxiliary collimators (2 secondary betatron and 2 secondary momentum)
  - (tune, orbit etc…)

Dense

Now it gets serious… should be ready to take 12 high intensity batches into each ring

- If TI 2/8 drift during injection → (auto-)re-steer final TI 2/8 elements
- Prerequisites:
  - All collimators in at specified positions. n1 = 6-7s , n2 = 7-8s sigma. Positions with respect to average closed orbit.
  - Ionization monitors operational
  - Local orbit feedback to preserve optimum protection
  - BLMs
- While all this going on:
  - b1, b3 correction,
  - Q-loop (pilot, intermediate & dense???)
  - & orbit feedback (only when there's beam…)

Interlocks etc...

Frightening

- Interlocks
  - Before the injection of a full batch one must ensure that all magnets in the transfer line and the LHC machine have their proper settings. If some magnets are not correctly set part of the injected beam can reach either the cold elements of the machine or some parts of the detectors.
  - Here one must keep in mind that the transfer lines use pulsed magnets and ensuring a proper setting of all the magnets requires a well defined checklist and interlock system.
- Lock controls
  - In the case of a full batch injection operation errors at the MKI and MSI elements can lead to hardware damage in the LHC machine. Thus, when changing from the pilot bunch injection mode to the full batch injection changes to the injection settings (this includes orbit changes at the TDI) must be excluded by an interlock system.

Controls & Instrumentation

- Calculate and steer angle and position of beam using BPMs and elements in transfer line.
  - Need accurate measurement of optics in lines to calculate x, x', y, y'
  - manual and automatic steering
- Display of injection screens, record profiles & positions
- Fixed displays of transfer lines
  - bunch currents, beam sizes, beam loses, beam position
  - logging of everything
- Bunch intensities as delivered by SPS per batch, along the batch
- Synchronisation
  - intensity selection, bunch configuration selection, ring selection & variations (inject at head or tail of circulating beam), diagnostics

Control II

- Trajectory measurement & correction
  - threading, injection errors, energy mismatch, injection oscillations,
  - batch to batch variations
- Matching
  - lines & LHC as one, OTR screens… etc.
- Collimator control
  - injection & cleaning, precise, accurate, with respect to closed orbit, need knowledge of optics & emittance
- Closed orbit control
  - lock orbit
    - collimators
    - kickers & septa
    - TDI
    - crossing angle
    - parallel separation bumps

Controls III

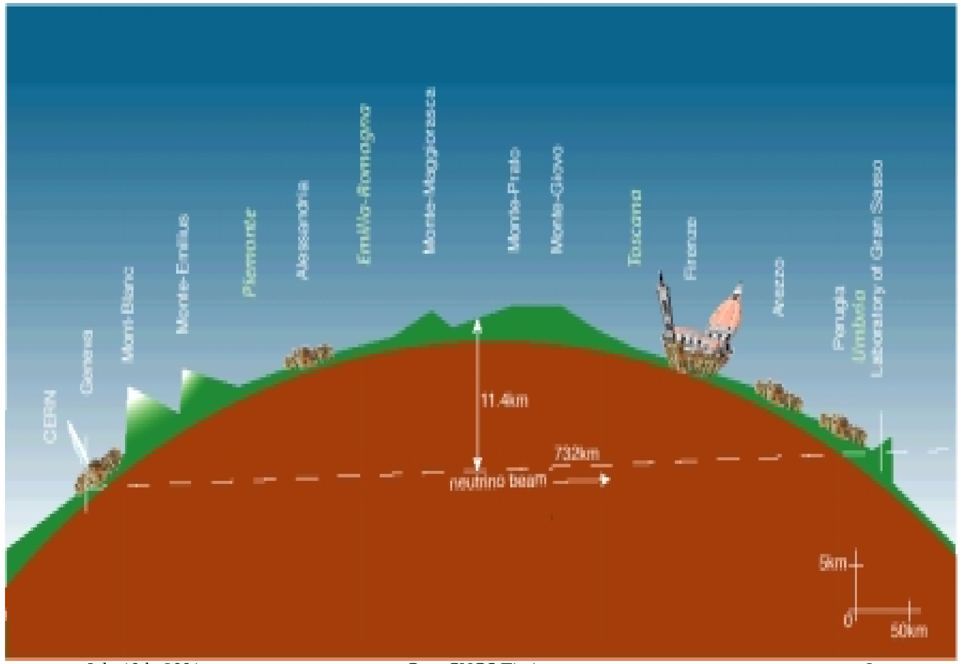
- Septa & Kicker control
  - timing, view kick etc.. automatic & manual
- TDI control
  - in terms of beam size, wrt to closed orbit
- TCDD
  - in & out
- RF:
  - Mountain range display, analog signals from pickups at end of lines,
  - Waveform acquisition: phase loop, injection transient signals.
  - control of phase, frequency, voltage etc.
- Clearly, as usual, settings management, logging, post mortem, on-line model...

Conclusions

- Precise and accurate control of injection process is mandatory
- Instrumentation and controls must be reliable
- Good diagnostics, good understanding and sophisticated control facilities will be required
  - bunch selection & the transfer process
  - monitoring and steering of the end of the lines
  - orbit control throughout the IP2 and IP8
  - matching
- Needless to say interlocks are vital
- Sector test will be less demanding but will provide a good opportunity to test many features.

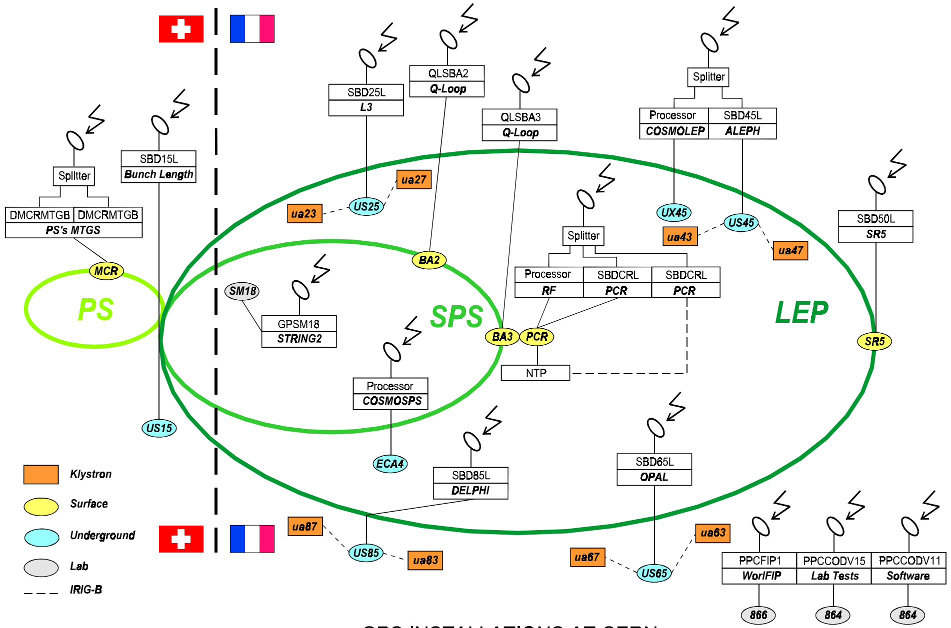
CNGS TIMING

- What is the problem?
- What is the solution?
- Why use it for CNGS?
- UTC measurements / SPS machine timing
- Proposed scheme
- Information transfer
- Networks
- Conclusions



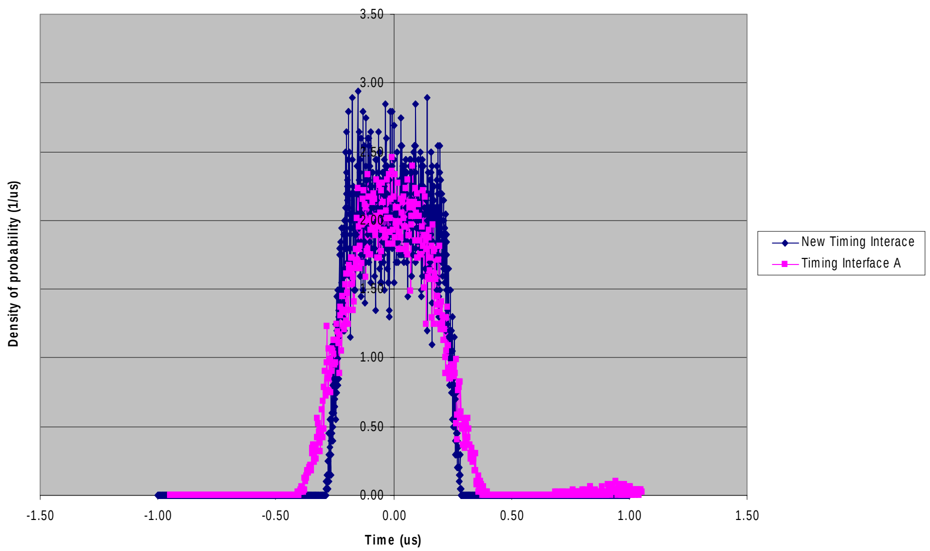
What is the Solution

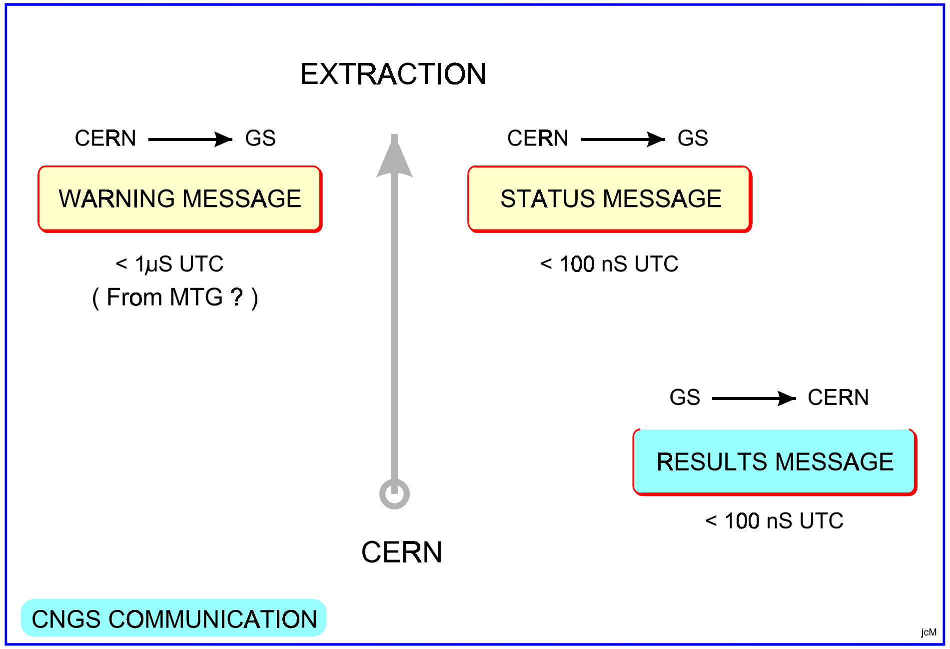
- Time of day, referenced to Universal Time Coordinated (UTC), provided by GPS systems located at CERN and also GS, for accurate time stamping. (<100 ns)
- Commercial networks for data communication in both directions.



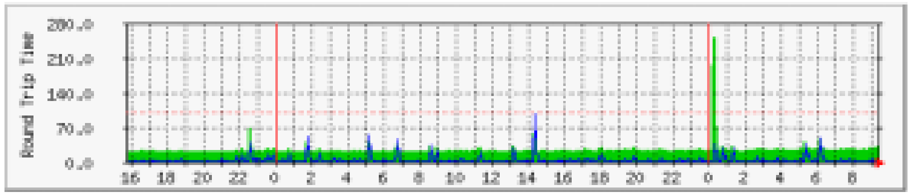
GPS INSTALLATIONS AT CERN

Jitter from 1 PPS from GPS and the milisecond output of Interface A and the new Timing Interface.



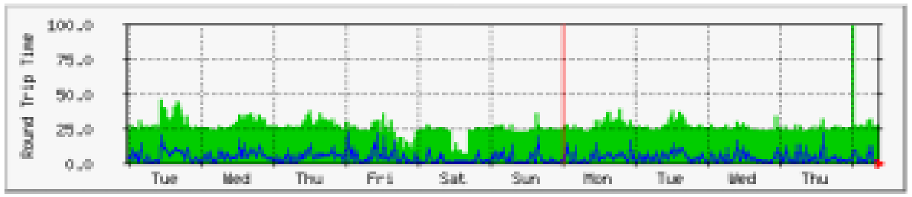


`Daily' Graph (5 Minute Average)

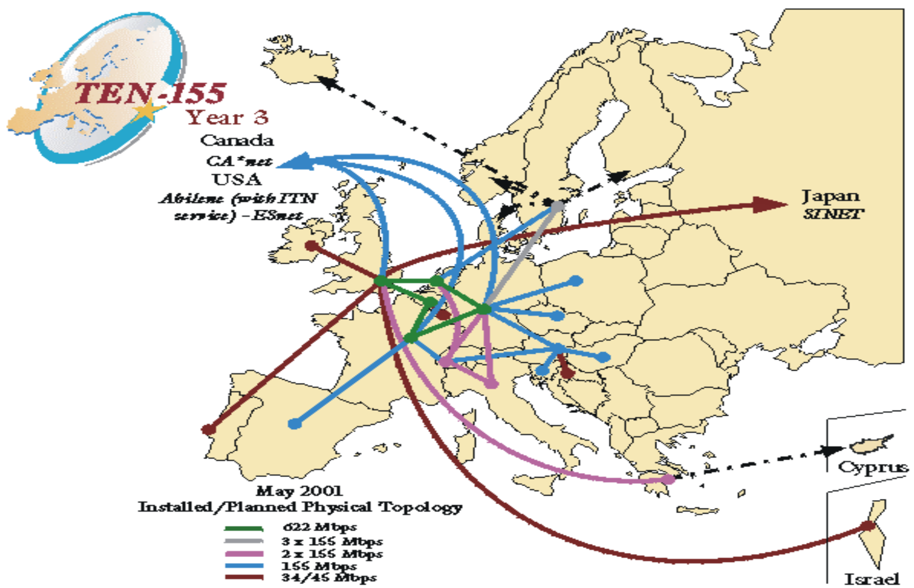


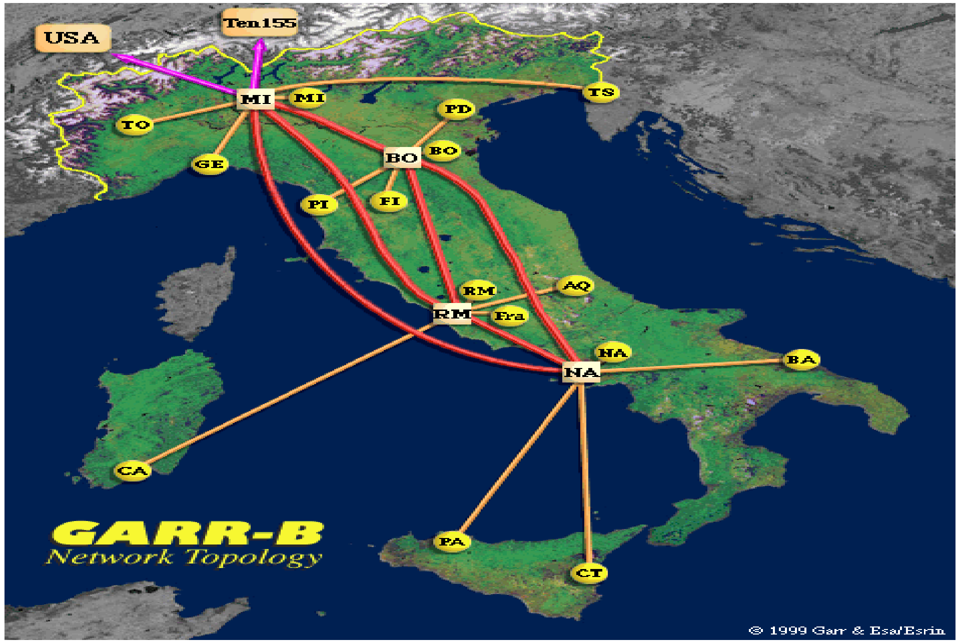
Max Avg: 254.0 msec (254.0%) Average Avg: 26.0 msec (26.0%) Current Avg: 34.0 msec (34.0%)
Max Std.: 97.0 msec (97.0%) Average Std.: 3.0 msec (3.0%) Current Std.: 6.0 msec (6.0%)

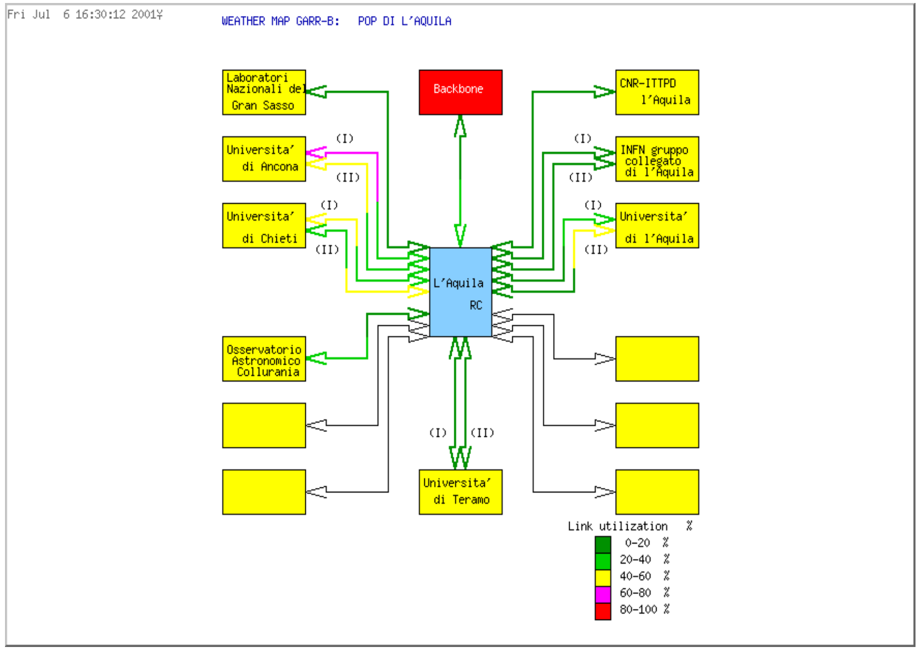
`Weekly' Graph (30 Minute Average)



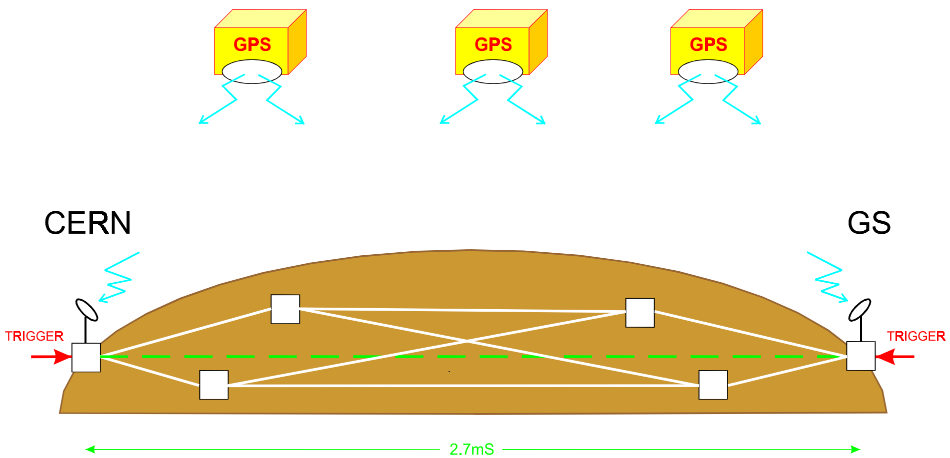
Max Avg: 100.0 msec (100.0%) Average Avg: 26.0 msec (26.0%) Current Avg: 28.0 msec (28.0%)
Max Std.: 22.0 msec (22.0%) Average Std.: 4.0 msec (4.0%) Current Std.: 3.0 msec (3.0%)







Proposed Timing Solution



JB RIBES 10/07/2001