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Data Management at JET with a look forward to ITER

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COntrol and **D**ata **A**cquisition **S**ystems (**CODAS**), Machine Operations,
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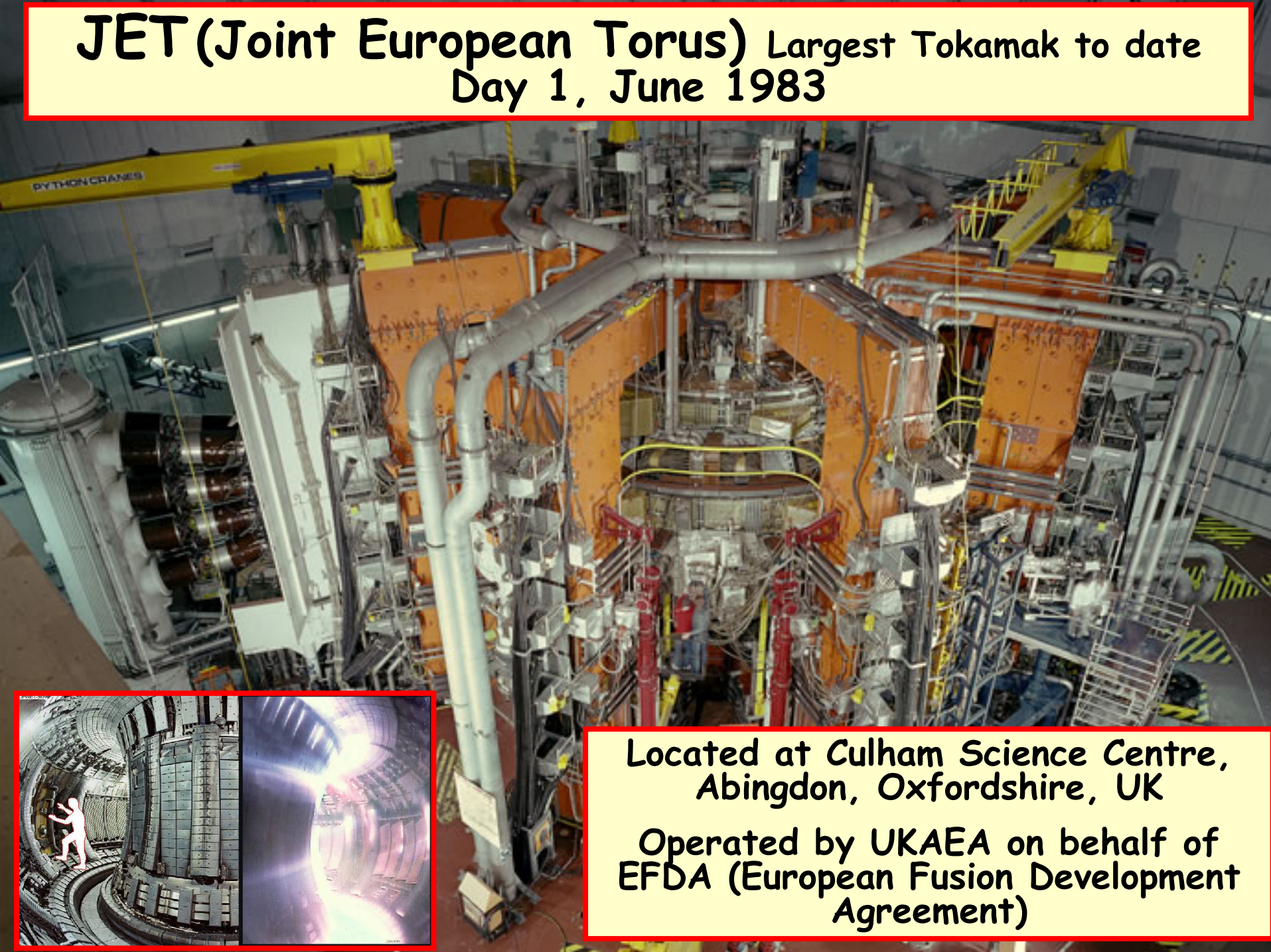
[*] See Annex 1 of M.L.Watkins, "*Overview of JET Results*", OV-1.3, Proceedings 21st IAEA Fusion Energy Conference, Chengdu, China, 16-22 October 2006.

JET (Joint European Torus) Largest Tokamak to date
Day 1, June 1983



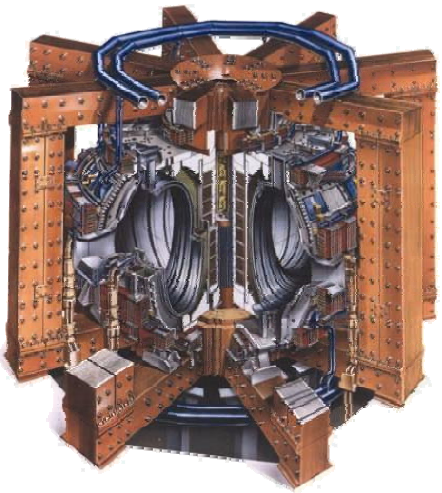
Located at Culham Science Centre, Abingdon, Oxfordshire, UK

Operated by UKAEA on behalf of EFDA (European Fusion Development Agreement)

JET (www.jet.efda.org) → ITER (www.iter.org)

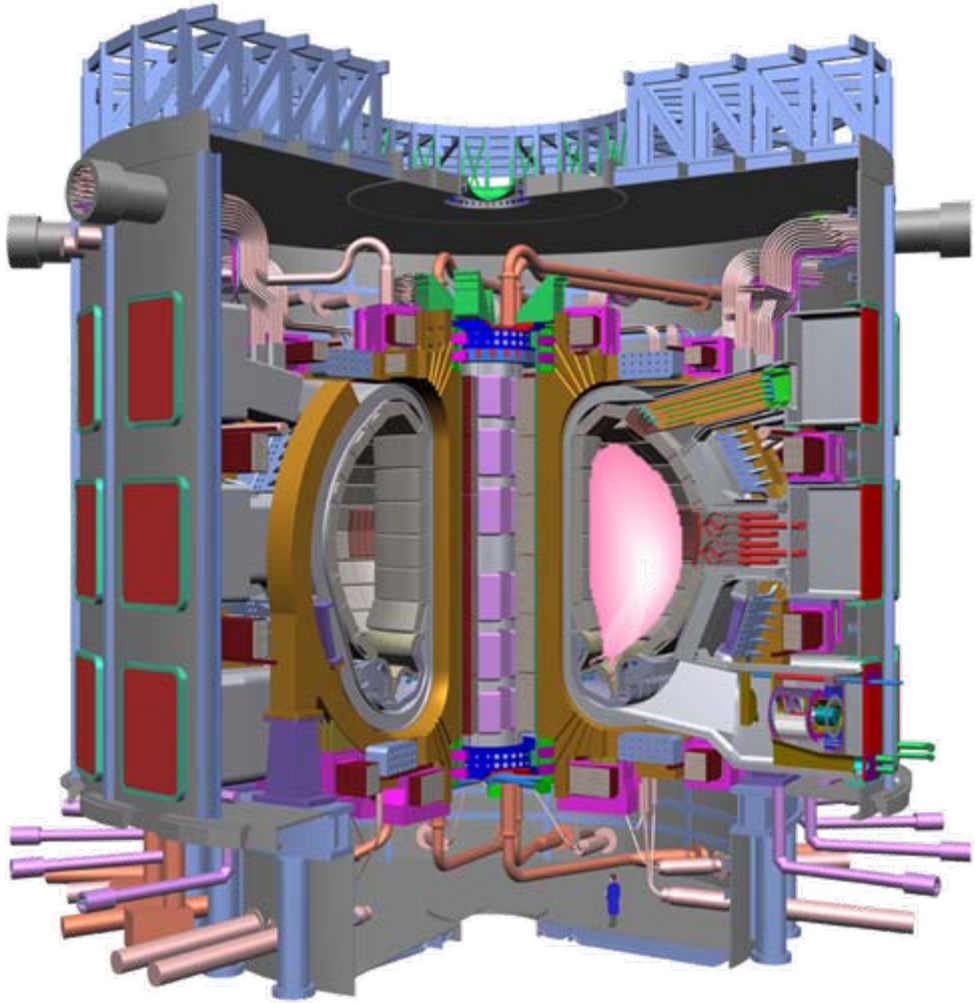
JET Enhancements

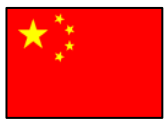
ITER relevant Engineering and Physics

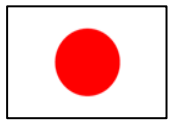


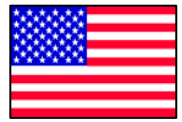
2x2x2

Plasma Volume x10





Data Management at JET

Finance, Contracts, HR

Planning

Plant Maintenance

Diagnostics Data Handbook

Experimental planning

Machine Configuration

Publications

Account management

Management systems

JET Control Systems

Experimental setup

Control

Data Acquisition

Data Analysis

Data Storage

Electronics Structured data

Document management

Change requests

Experimental Logs

Fault Reporting

Network Management

Access Control

Statistics

Not all as integrated as we would like

Hierarchical and Modular Architecture

Three-level hierarchical and modular control system structure in hardware and software:

Central/Supervisory	- level 1
Subsystem	- level 2
Component	- level 3

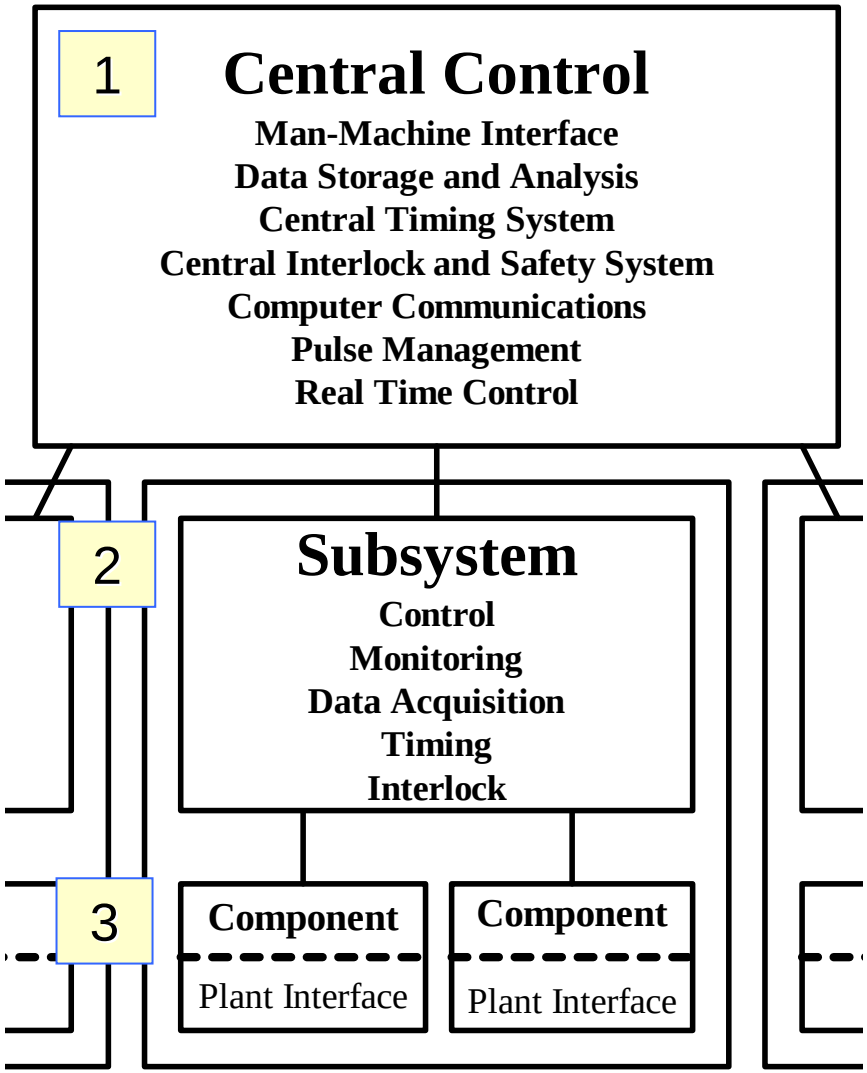
Subsystem per major Plant System
Vacuum, Poloidal Field, RF Heating ...

10 Subsystems for ~70 Diagnostics

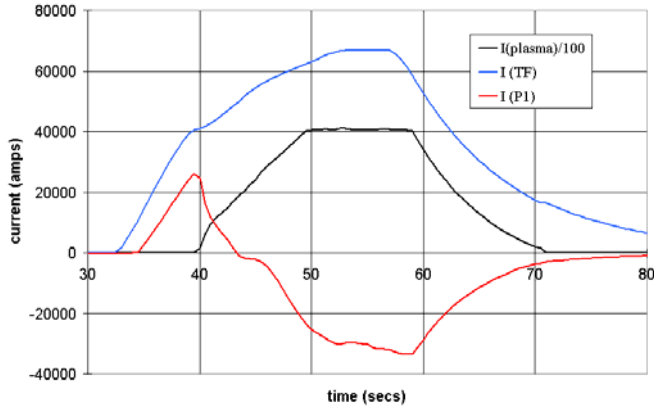
Same structure applicable to Machine Control and to Diagnostics

21 subsystems in total

Autonomy at Subsystem Level



JET Experiment Pulse Cycle



Offline Analysis

Pulse Preparation

Control/Diagnostic

Setup/Validation

Countdown

Pulse

Data Collection

Data Storage

Intershot Analysis

JET is pulsed

25 pulses per day

~70,000 since 1983

Two shifts 06:30 – 22:30

Pulse every ~ 30 minutes

~30-40s of plasma

Maximise Repetition Rate

ITER will be pseudo-continuous

(60mins of plasma)

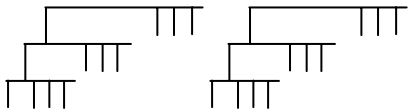
Pulse Preparation, Setup, Validation

Hierarchical State Machine

JET

Subsystem

Hardware Experiment



JET-written ~1981

Component

Level-1 software tools

Pulse Preparation - Cross-Subsystem (Level-1)

Single view of plant, 22,000 parameters

JET-developed ASCII database – sets values in L2 databases

Experimental Schedules and pulses, old pulse settings

400 Plug-in codes, Scenarios, "Flight Simulation"

Same tool + DB, different views for Physicists, Engineers

Machine Setup, Machine Safety Pre/Post pulse checks,

Control/Setup - Subsystem (Level-2)/Component (Level-3)

Plant Status Image = LiveDatabase built from hardware tree

Pre/Post-Pulse actions (experiment tree)

Data-driven :- Synoptic Displays, Continuous Recording,Trend Displays Alarms, Setpoints, Waveforms, Level-2 Logic, Component Frameworks, RDF-based CODAS Configuration Language

Real-time Applications, Ethernet, ATM, ATCA, analogue

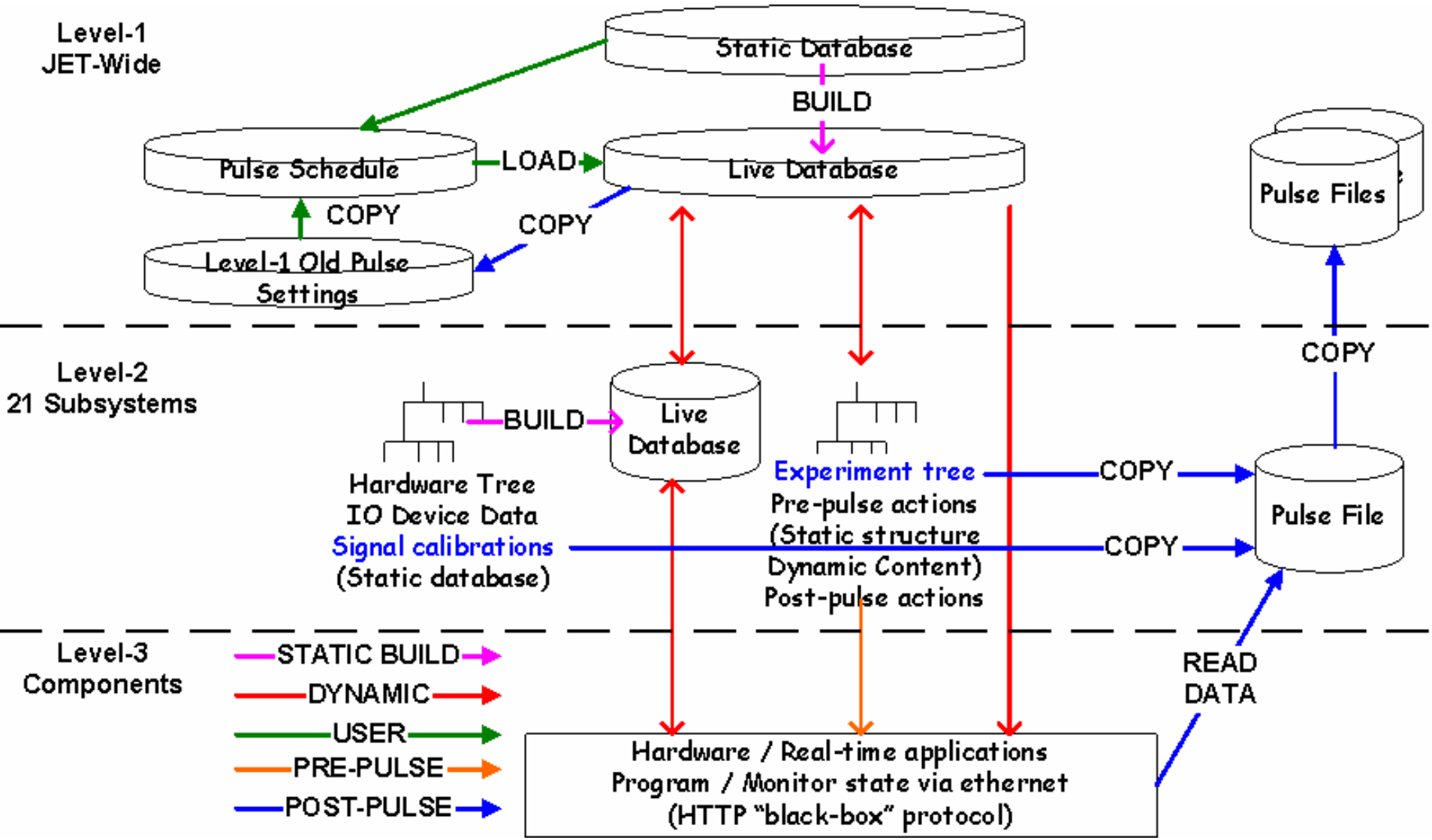
VME (VxWorks, 68k, PPC), PC (Windows, Linux), CAMAC

Plant Interfaces

CAMAC, Eurocard, VME, PCI, CPCI, RS232, GPIB, PLCs, ATCA

Ethernet – HTTP protocol - "Black-boxes" c.f. ITER Plant Systems

Control System Databases



Real-time Control

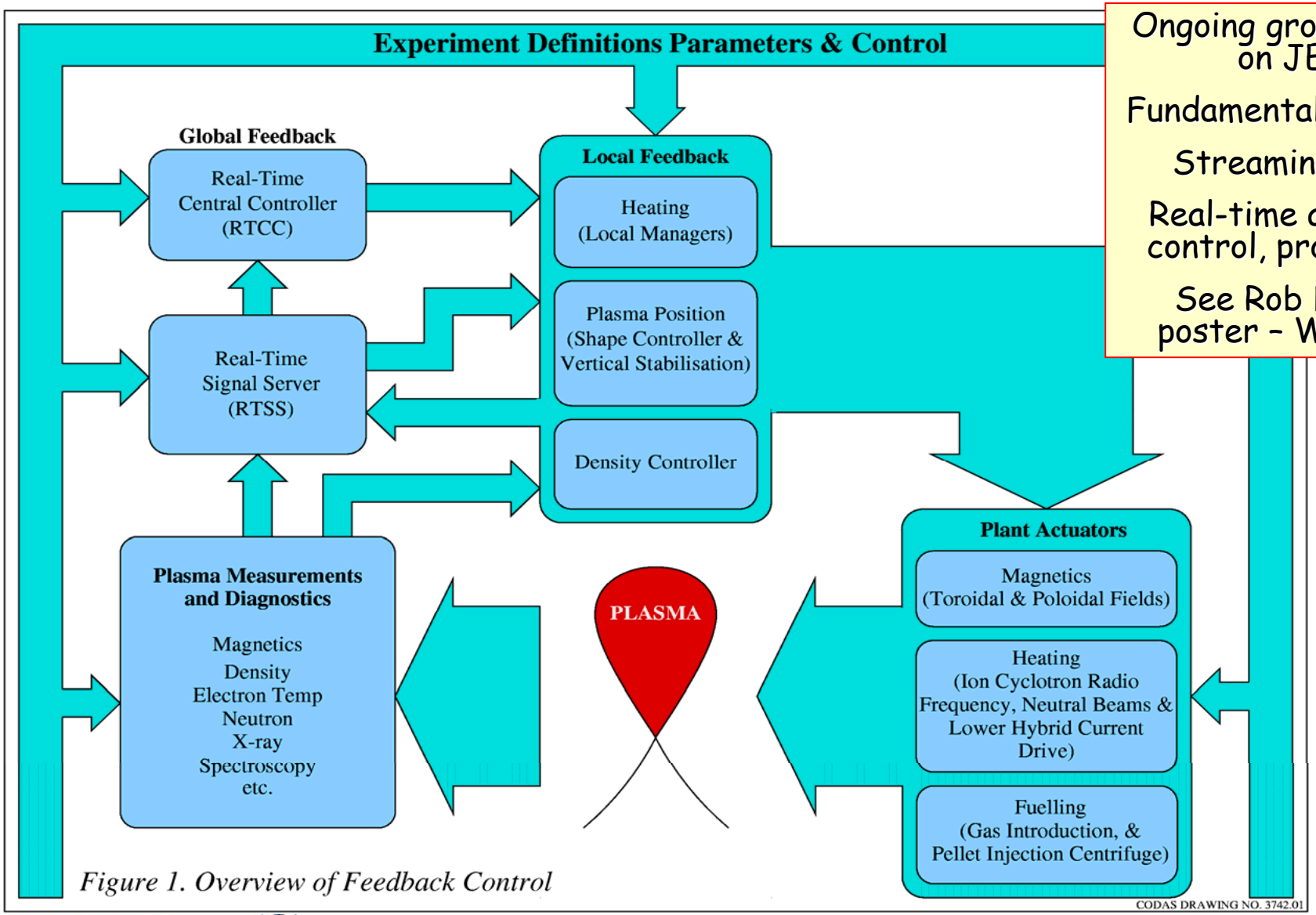


Figure 1. Overview of Feedback Control

Ongoing growth area on JET

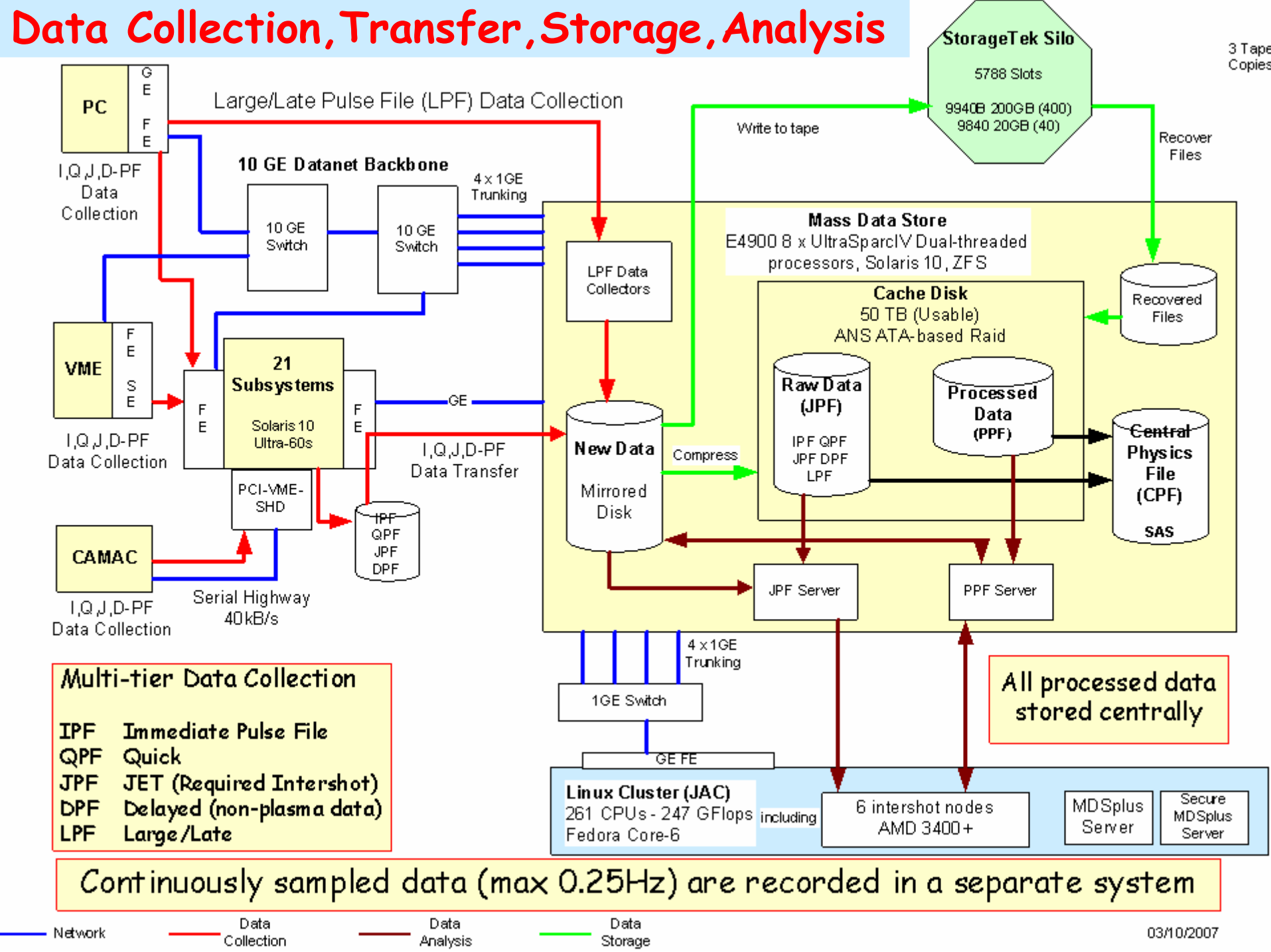
Fundamental on ITER

Streaming data

Real-time analysis, control, protection

See Rob Felton poster – WPPA22

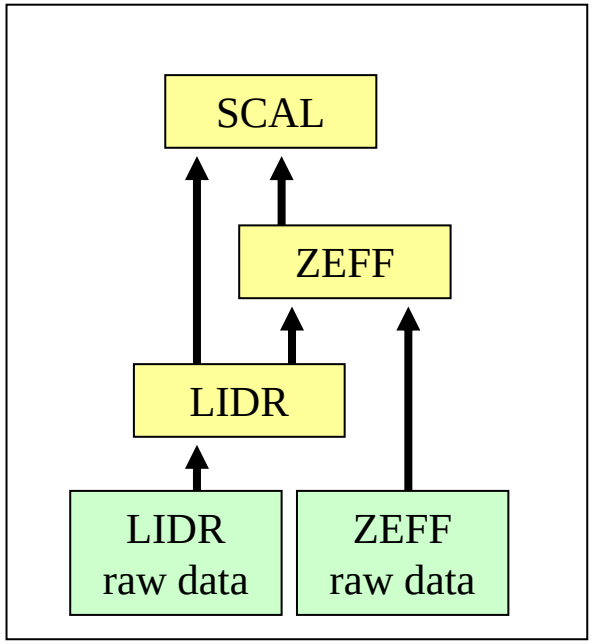
Data Collection, Transfer, Storage, Analysis



Intershot Data Analysis

Scheduling Problem

- ~80 codes are run intershot
- Database models dependencies of codes on raw data and each other (processed data)
  - Critical path analysis
- Codes scheduled in parallel based on dependencies
- Multi-tier collection strategy
  - Fine tuning of raw data availability
  - Critical part of intershot is complete before end of data collection
- Communication via processed data files
  - Some work on web using services
  - Integrated data analysis
- JET-like intershot analysis will not exist on ITER
  - Must be available in real-time



Mass Data Store

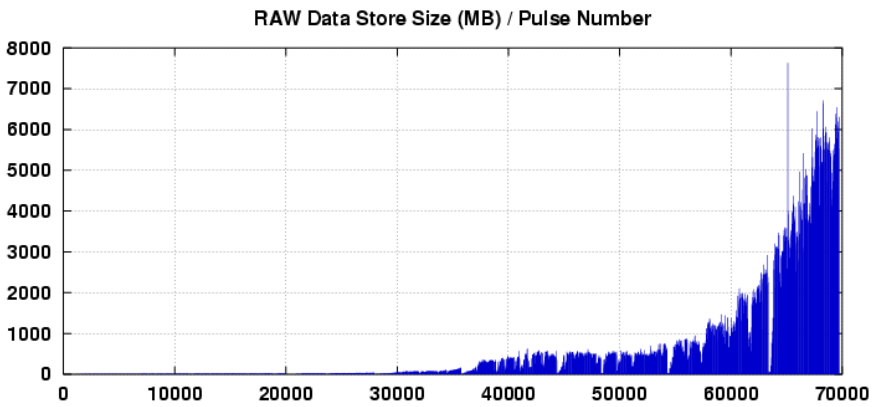
- Raw Data (IPF,QPF,JPF,DPF,LPF) – Read-Only
  - All data accessed via subsystem + pulse number(=file) and signal name
  - Home-grown (1981) data format, File headers contain signal information
  - Client-server data access
  - Home-grown file system-based indexing system holding meta data, ZFS
- Processed Data (PPF) – Read / Write
  - Client-server data access
  - MIMER RDBMS
    - Meta data indexing system
    - Access by pulse number, signal name
  - NetCDF data files
  - File management same as for raw data
- Central Physics File (CPF)
  - SAS Database
  - Access via SAS or SQL
  - Migrating to Postgres for the underlying data
- MDSplus provides remote data access

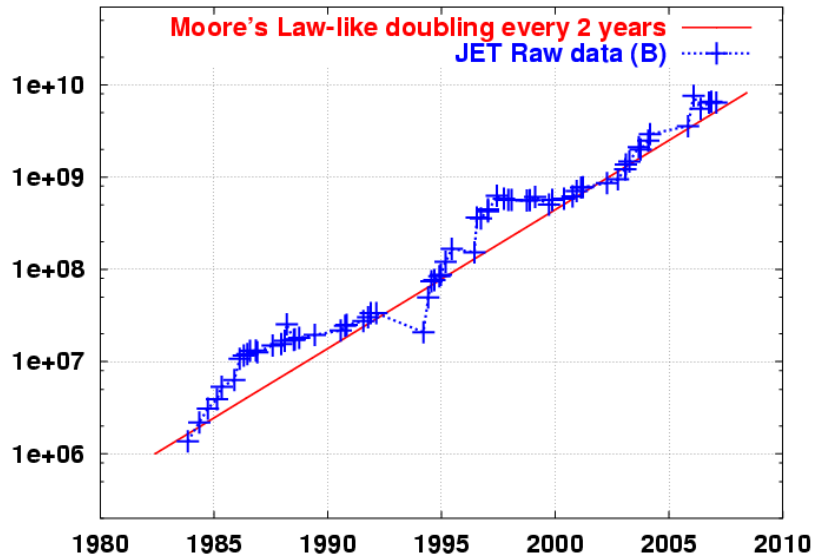
MDSplus – Model Data System

- See www.mdsplus.org
- MIT, CNR RFX-Padova, LANL – first developed late-1987
- ".. allows all data from an experiment or simulation code to be stored into a single, self-descriptive, hierarchical structure"
- JET provides MDSplus glue layer to raw (JPF) and processed (PPF) data
- Most Tokamaks provide MDSplus server
- Many analysis and display programs are MDSplus aware
- Installed in > 30 Labs world-wide, De-facto standard (ITER will keep concept)
- Provides Remote Data Access (RDA)
- Globus version using X.509 certificates for authentication, e.g. remote writes

- MDSplus provides the basic **functional** requirements of the ITER data access system from the users perspective
- Extensions have been proposed to cover continuous data acquisition as part of the ITER conceptual design

JET Experimental Data Volumes

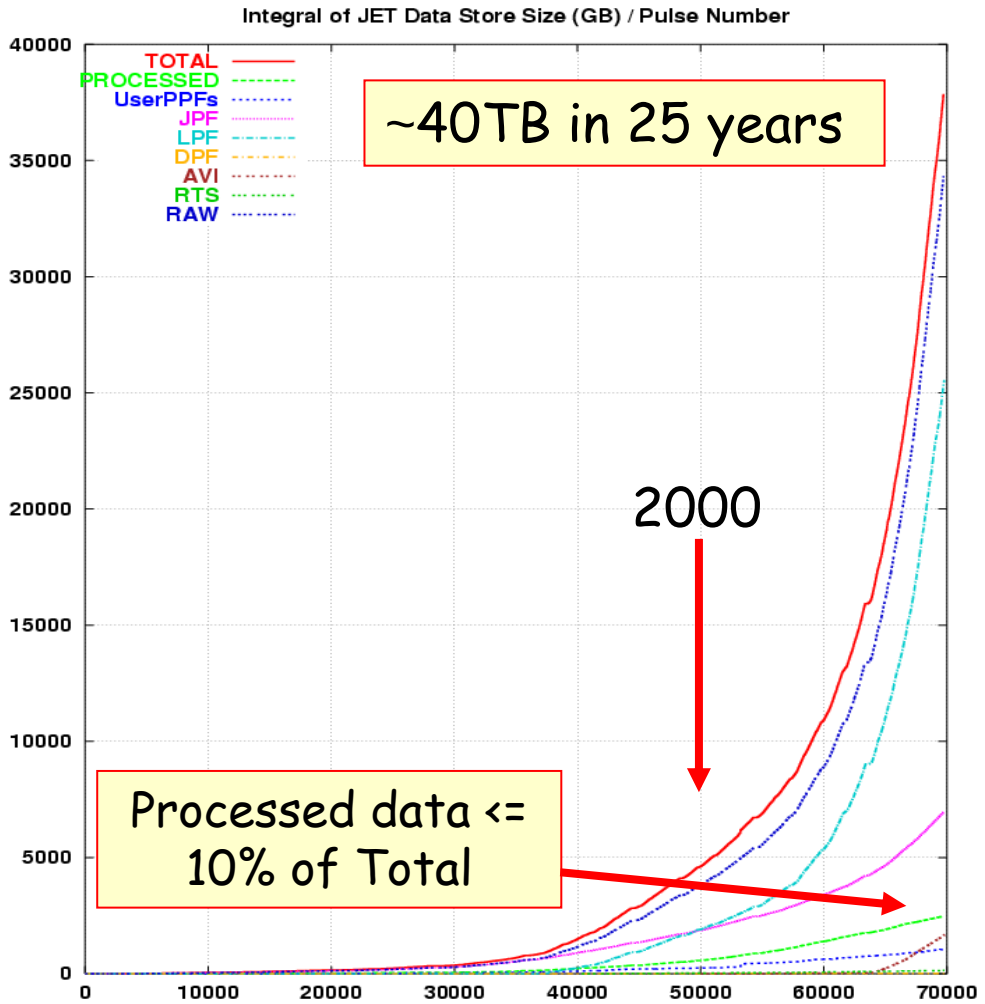




~10GB / pulse = 0.25TB/day

2010 ~60GB / pulse ?

c.f. LHC 10PB/year ?



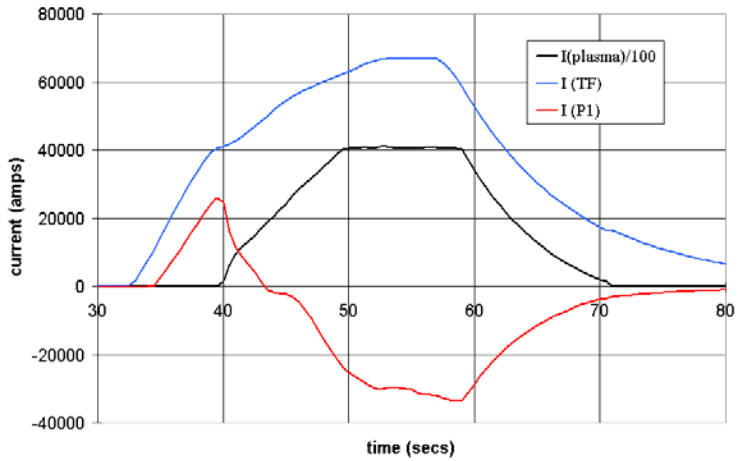
Simulation data volumes are becoming significant

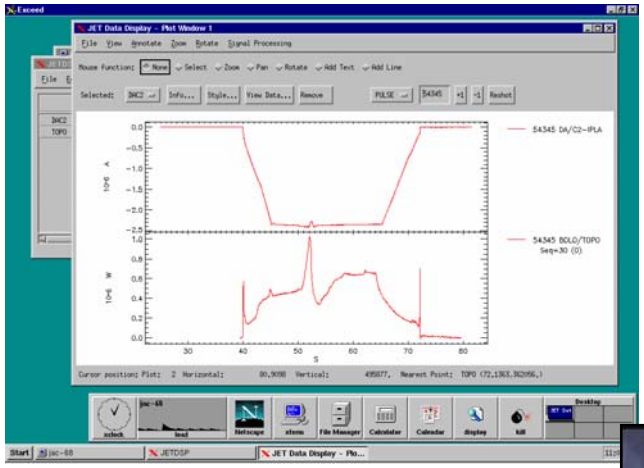
Where will ITER be different? (1)

See Jo Lister talk "Status of the ITER-CODAC (**CO**ntrol **D**ata **A**ccess and **C**ommunication) Conceptual Design", ID=1422, 08:30, Thursday

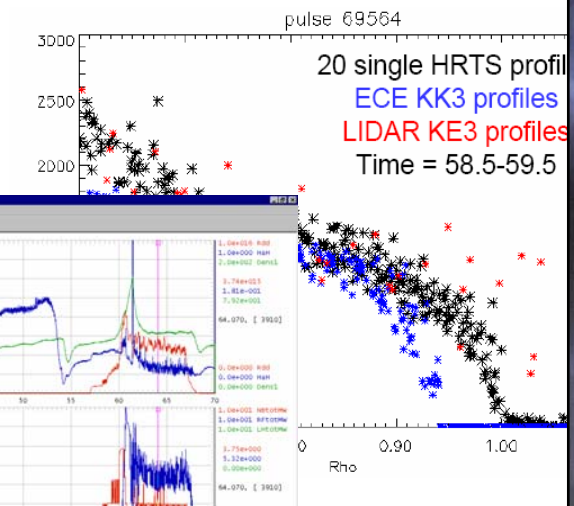
- Long-pulse / Pseudo-continuous
  - Merge pulsed and continuous data acquisition
  - Streaming data with varying sampling rates
  - Same for all data sources e.g. CODAC internal data
  - Single access layer to all data
  - Single signal naming scheme as part of a wider plant naming scheme
    - Rules to be developed, URIs (RFC 3986), managed namespaces, Qnames
  - Data access via absolute time
    - But pulse number and relative times to events in pulses / segments
  - Novel data mining and data classification techniques

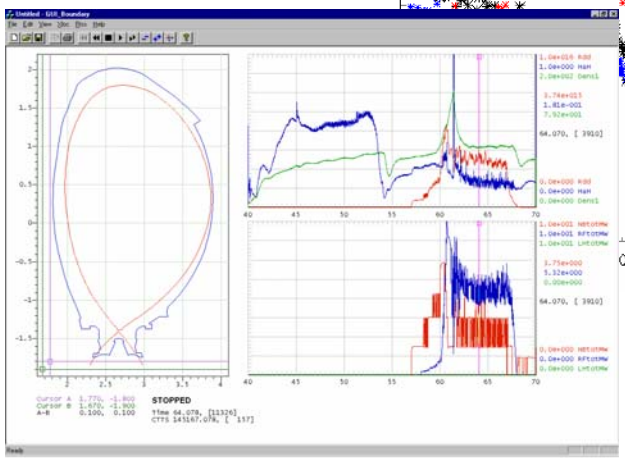
All fusion data is time series

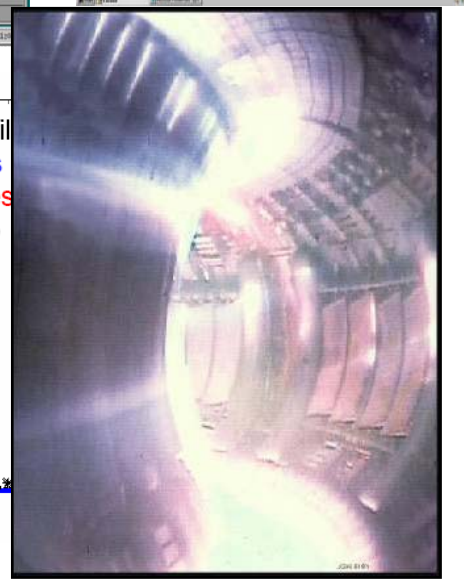




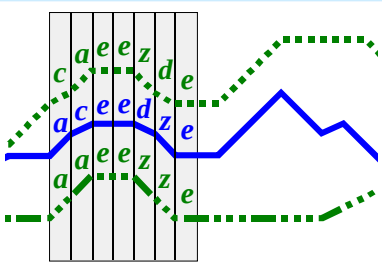
Long-pulse experiments imply new techniques for data analysis

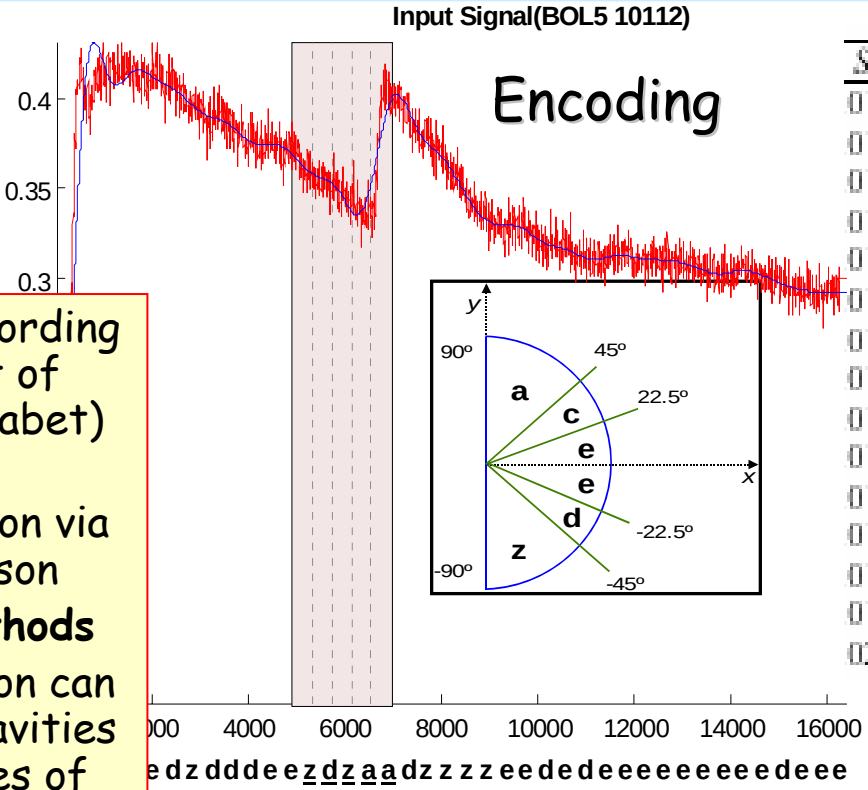




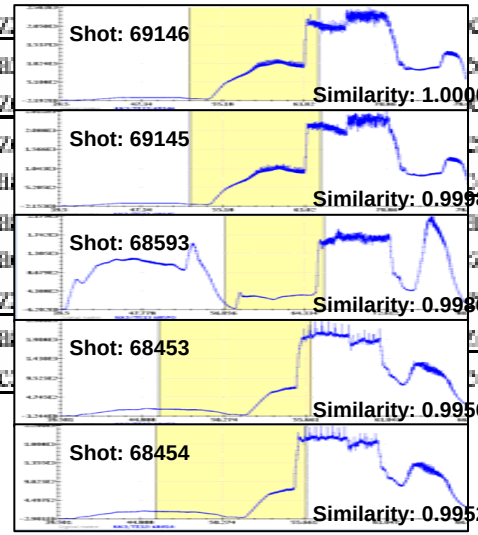


Pattern recognition – RDBMS + SQL





Shot	Code
0108	aaazzzddeeeeeezaazzdzzeeeeeeeeeeeeeeeeee
0109	aaazzzzzzzzzdeedeeeeeeeeeeeeeeeeeeeeeeee
0110	aaazzzzzzzzzeeeeeeeeeeeeeeeeeeeeeeeeeeee
0112	aazaedzdddeezdzaadzzzzeedeeeeeeeeeedeee
0115	aaazzzzzzzzzddeedeeeeeeeeeeeeeeeeeeeeee
0116	aaazz
0119	acaa
0120	aaaz
0121	aaaz
0152	azaa
0153	aaaa
0155	aaaa
0176	aaaz
0194	aaaa
0222	aaac



Data encoded according to discrete set of values (code alphabet) f(gradient)

Pattern recognition via string comparison

Alternative Methods

Pattern recognition can be based on concavities or other features of the signals

SQL query

```
select * from Codes where Type like 'BOL5' and
                (Code like '%[z,d][z,d][z,d][a,c][a,c]%' or Code like '%[a,c][a,c][a,c][z,d][z,d]%')
```

Flexible search ⟷ Flexible search

Opposite polarity

J.Vega CIEMAT

Where will ITER be different? (2)

- All project data can have an associated time
  - Requirement to play back history – training or enquiries into incidents
  - Software, configuration data as well as plant data
  - Concept of future as well as past e.g. for experiment planning purposes
  - Full data provenance
    - publications back to ADC boards, firmware, software versions …

- Slow control (e.g. machine conditioning) = Plasma Control
  - Single Schedule Editor and real-time Scheduler is required?
  - Just a question of scheduling with different time scales?
  - Extend to Experiment planning, Maintenance scheduling, Shutdown planning?
    - Campaign = Year, Shutdown planning=year/month/day, Experiment = Week/Day, Session = Day/Half-Day, Pulse=Hour, Machine conditioning=Hour, Maintenance scheduling=Month, Segment in pulse=Minute, Control mode=Second, Plasma Event=millisecond

- Real-time analysis, control, protection
  - General trend on fusion devices today, See Rob Felton poster – WPPA22

Where will ITER be different? (3)

- Data Volumes and Rates
  - ~10PB/year in 2016? c.f. LHC
  - ~10GB/s
  - Underestimates?
    - 1977 JET design figures JET suggested that less than 20GB data would be collected to the end of the project life in 1990. (170GB were collected).
- Much more modelling, model data set sizes will be significant
  - Simulations running in real-time, comparable data volumes?
  - 1m of burning plasma simulation = 1TB
- Archive all raw data ? Only novel data ? …
  - Cost is small by comparison to ITER investment so archive all
- Data mirroring at partner sites?
  - provides backup functionality

- Internet age
  - Commercial / open-source solutions widely available
  - Very little should be developed in-house

ITER – Single Project-wide Database?

- Single logical database to last the project lifetime
  - Documents, CAD, Structured Data, Plant Naming System, Signal Naming Scheme, Software, Planning, IT
  - Construction, Operations, Maintenance, Decommissioning
  - Administration, Engineering, Physics
  - Experimental Planning, Operations, Data Storage, Analysis, Publications
  - Control and Data Acquisition Systems
    - Data driven and generated from the database
  - All data has an associated time – keep history - full provenance
  - Management Systems
    - Processes, Quality, Risk Management, Obsolescence Management …

- Self-description of the plant systems delivered "in-kind" – 7 partners
  - Cubicles, modules, wiring, signals, software, firmware, history …

Summary

- JET hierarchical and modular system architecture
  - Hierarchical ~1981 subsystem (level-2) databases still in use
  - Level-1 control layered above - JET-wide setup, increased functionality
  - Raw data pulse file data formats unchanged since ~1981, processed data file formats have changed
  - Client-server - underlying technology changes hidden from end-users

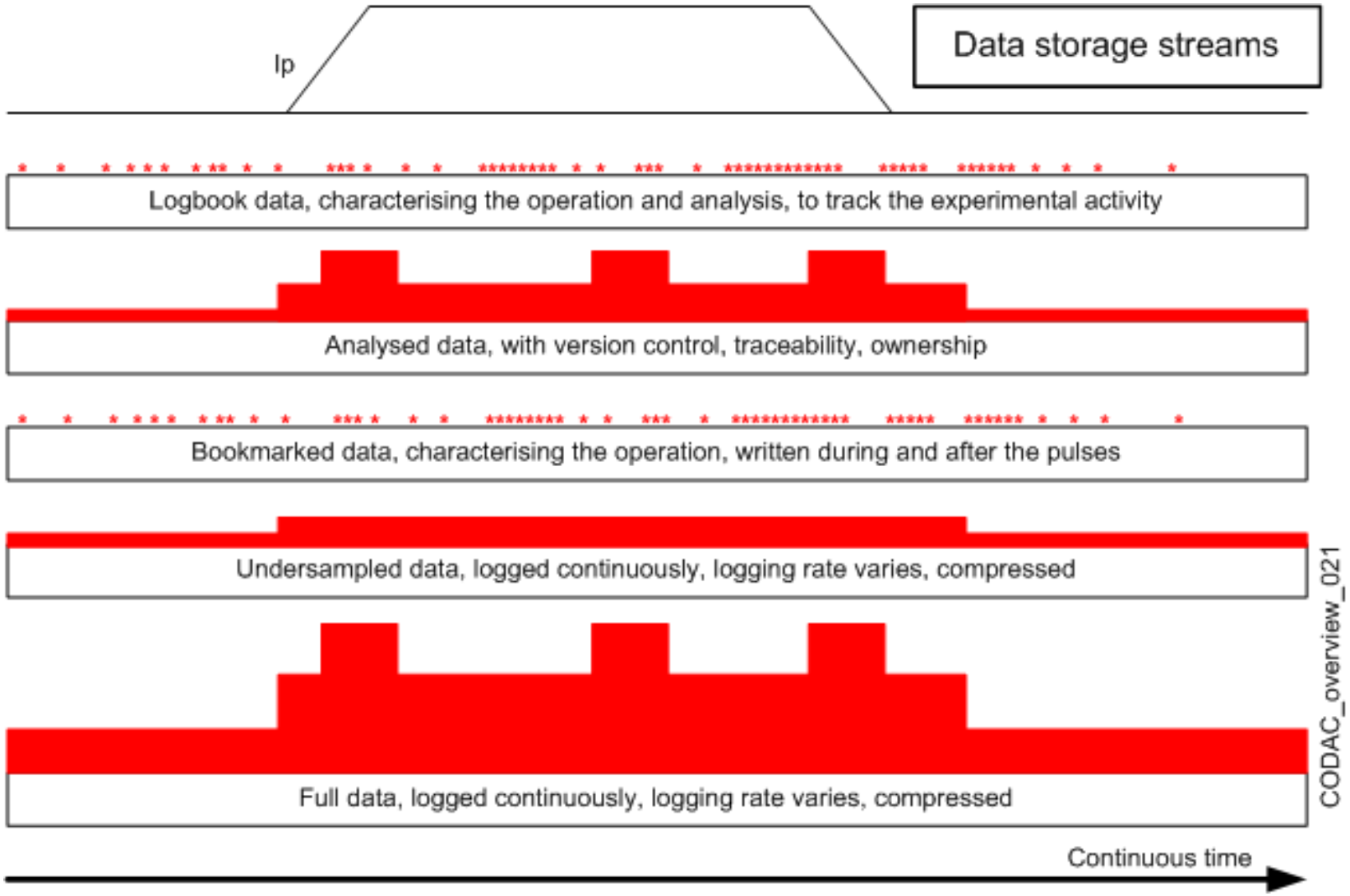
- JET has large number of heterogeneous support databases
  - Developed at different times, by different groups and using different technologies – in-house and commercial systems
  - Integration between them is not always ideal

- ITER is starting with a clean sheet
  - All-embracing project-wide database to last the project lifetime
    - Derivation of control system data

End

backup slides

ITER (2) – courtesy jo.lister@iter.org



SQL:2006

Merge RDBMS and XML technologies

"ISO/IEC 9075-14:2006 defines ways in which SQL can be used in conjunction with XML. It defines ways of importing and storing XML data in an SQL database, manipulating it within the database and publishing both XML and conventional SQL-data in XML form. In addition, it provides facilities that permit applications to integrate into their SQL code the use of XQuery, the XML Query Language published by the World Wide Web Consortium (W3C), to concurrently access ordinary SQL-data and XML documents"
http://en.wikipedia.org/wiki/SQL

Data-driven control system based on web services?

ITER (4) – Data Volumes

Simple Extrapolation from JET to ITER

JET 50-60GB/pulse 2010, 150 days, 25 pulses/day

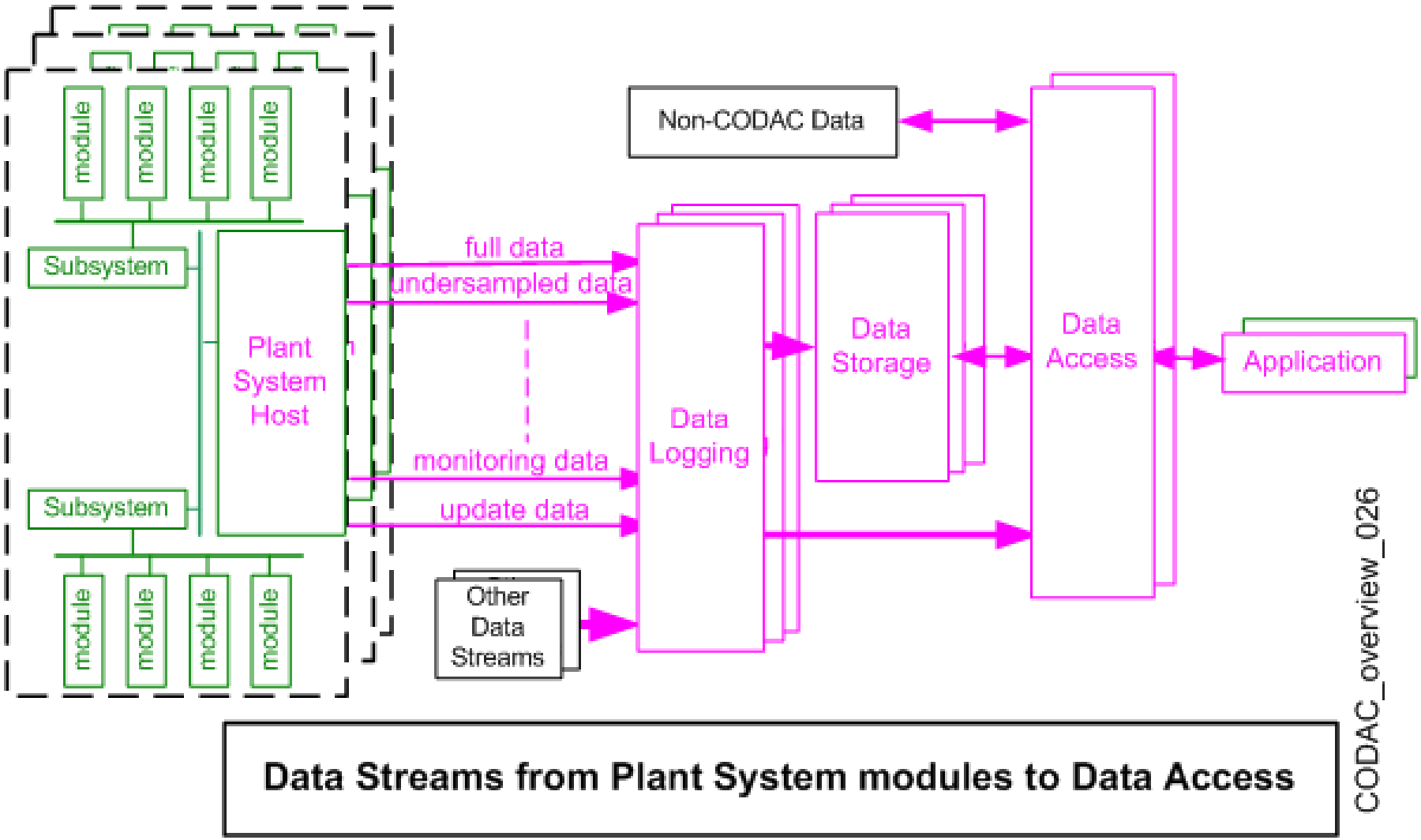
ITER – Same number of plasma seconds/year

60 x 2 x 2 x 2 = 480GB/pulse in 2016

480 x 25 = 12TB/day x 150 = <10PB /year in 2016

c.f. LHC 10PB/year in 2007

ITER (3) – courtesy jo.lister@iter.org

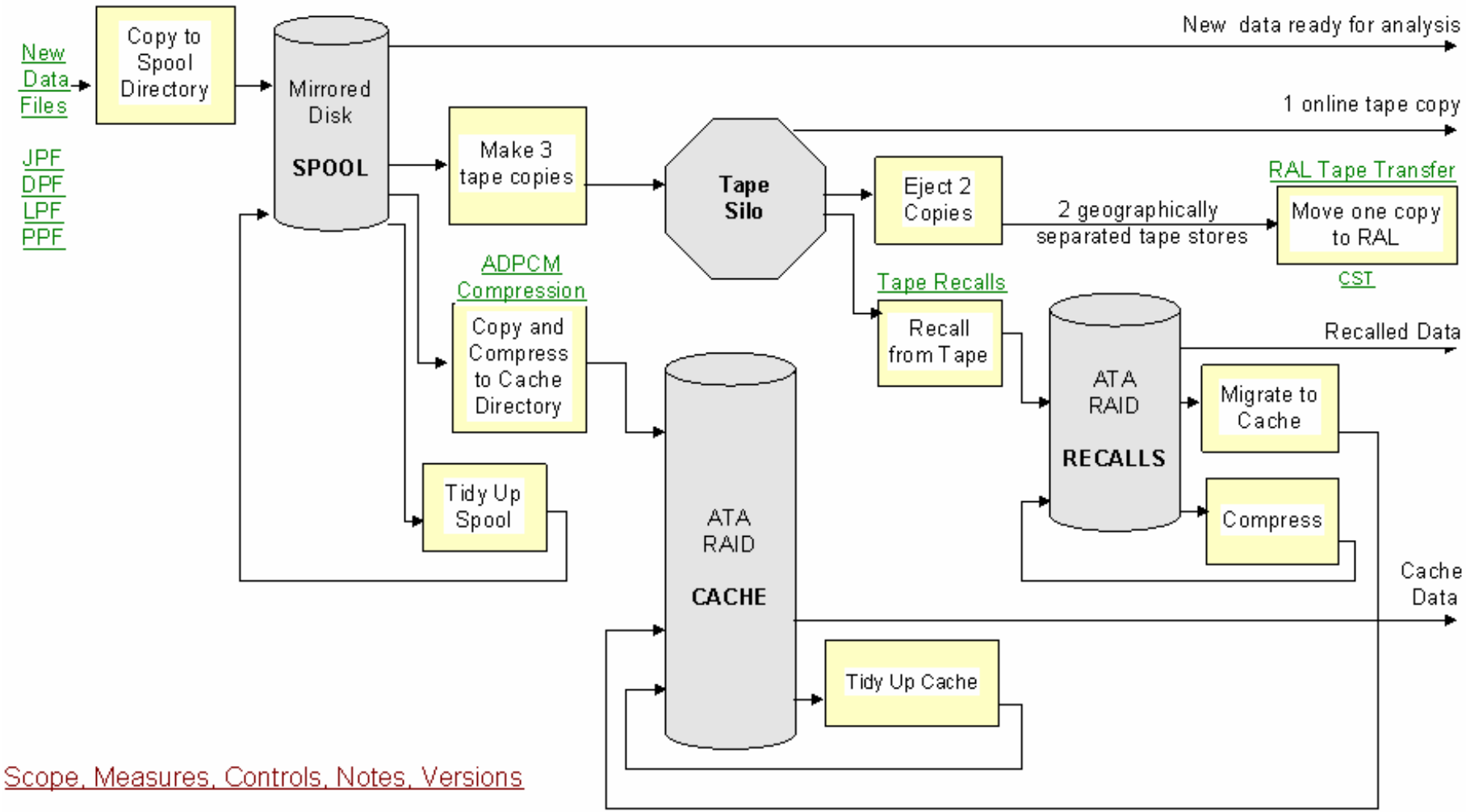


Data Streams from Plant System modules to Data Access

Mass Data Store Technology (1)

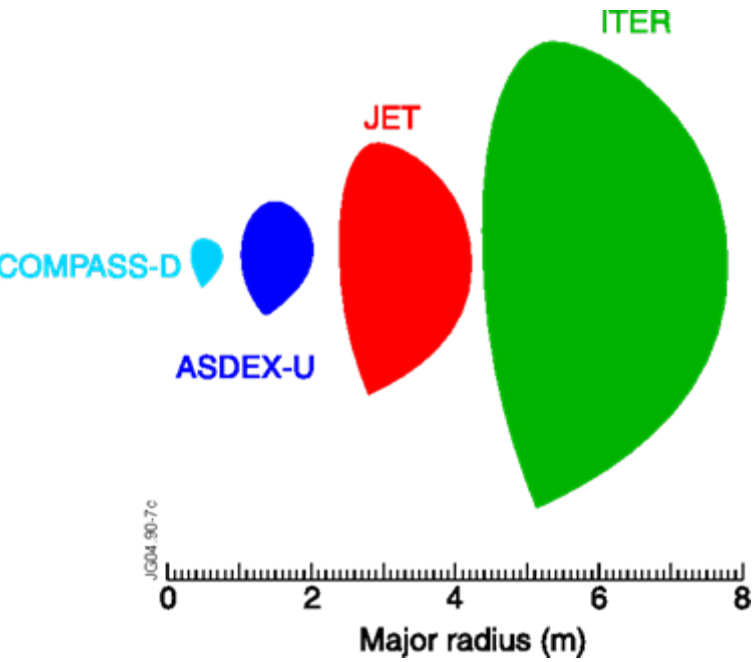
- SUN E4900 server
  - 2 x (4 UltraSparc4 1.2GHz dual core processors with 32GB RAM) S10
  - Zones used to isolate services
- Trunked 4*1Gb/s ethernet for incoming and outgoing data
- 3 separate disk areas
  - Spool - 0.7TB ANS ATA-based mirrored disk for incoming data
  - Cache - 60TB ANS ATA-based RAID cache disk – 57% full
    - Raw data is compressed (ADPCM)
    - Cost-based deletion algorithm
  - Recalls – 0.5TB ANS ATA-based RAID
- ZFS
  - Migrated from SUN Volume Manager and UFS during 2007
- Veritas Netbackup
  - Not ideal. Replace by what ? Home-grown system? SAMFS ?
- 9940B (200GB native) StorageTek drives
  - ACSLS tape management (Oracle)
  - 3 tape copies - security

Data File Management

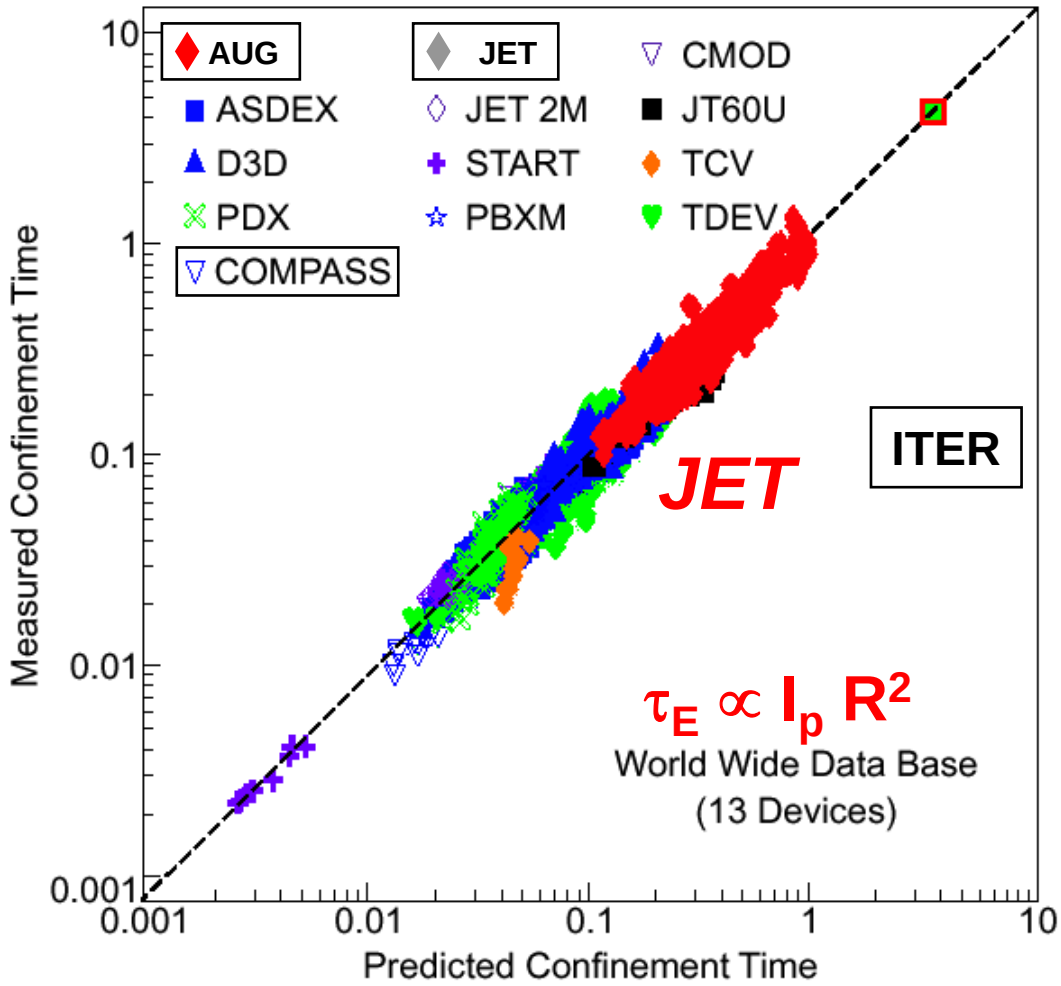


Cost-based deletion algorithm f(last access time,size) to manage the cache space

JET provides key contributions to predict ITER performance

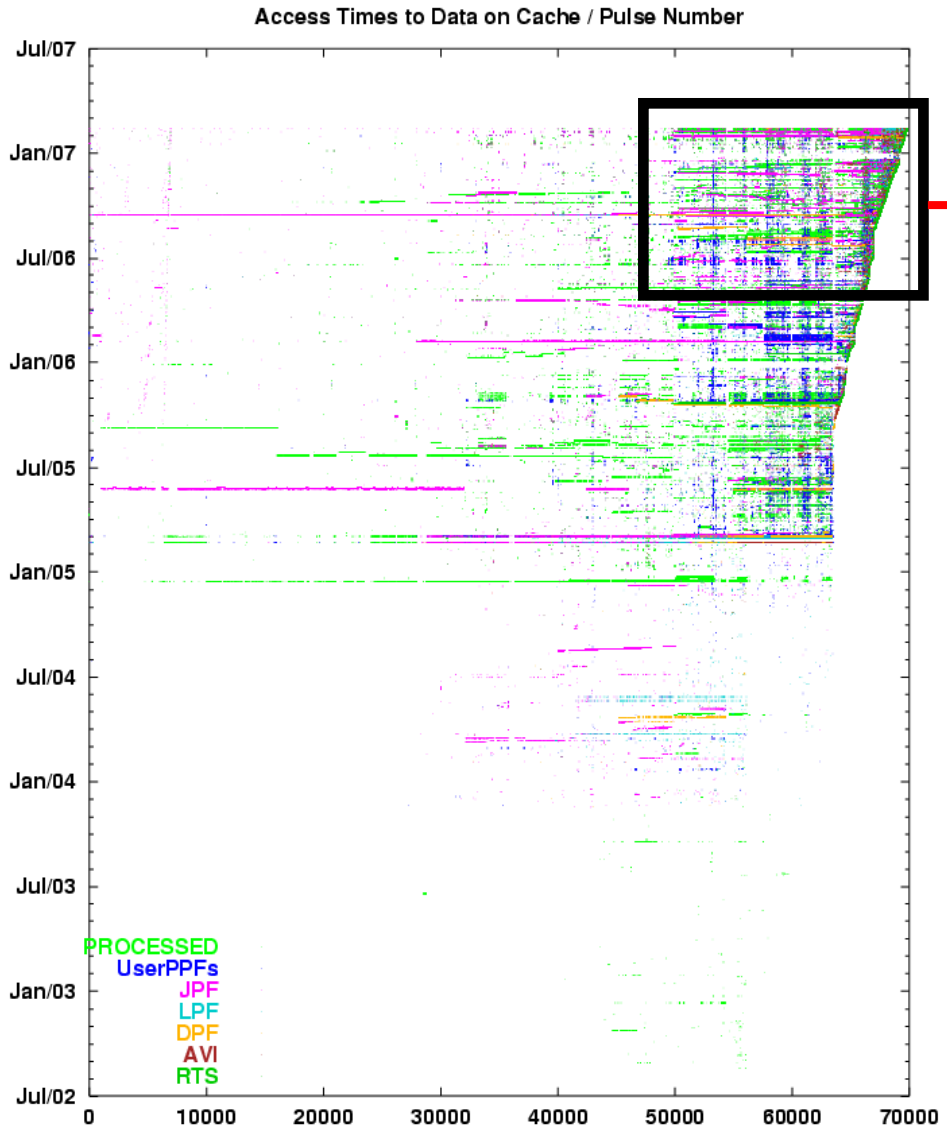


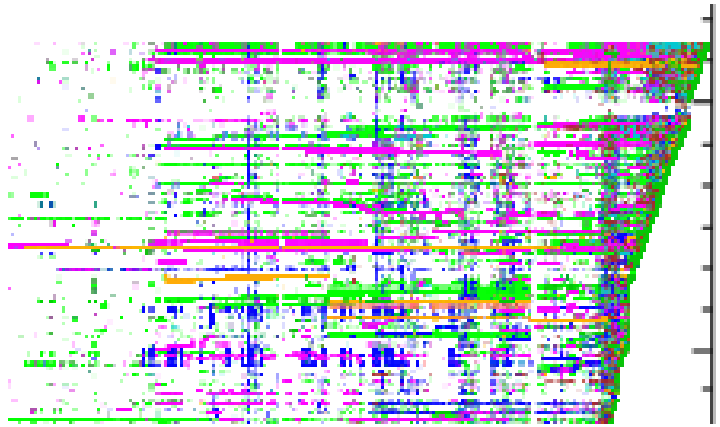
Cross section of present EU D-shaped tokamaks compared to the ITER project



Confinement time $\tau_E = W_{plasma}/P_{input}$

Data Access

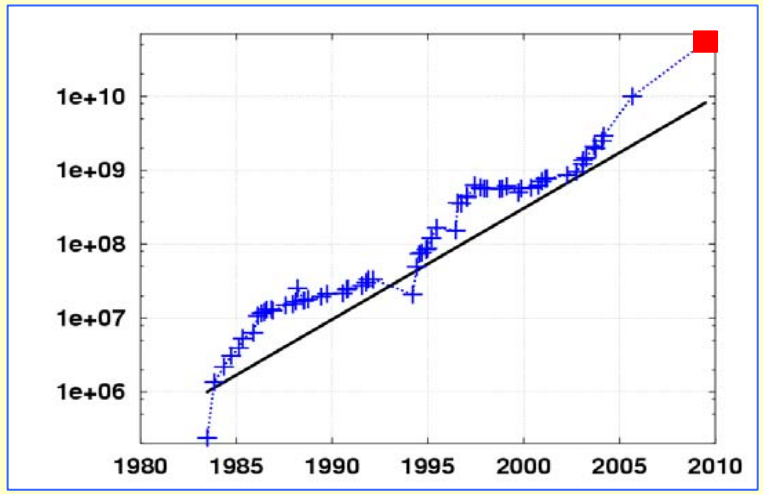




- The data shows file access times although fusion data is analysed at signal level, not files
  - Client-server technology, JPF server, PPF server, MDSplus server
  - The servers retrieve files from tape and extract signals

JET Prospects

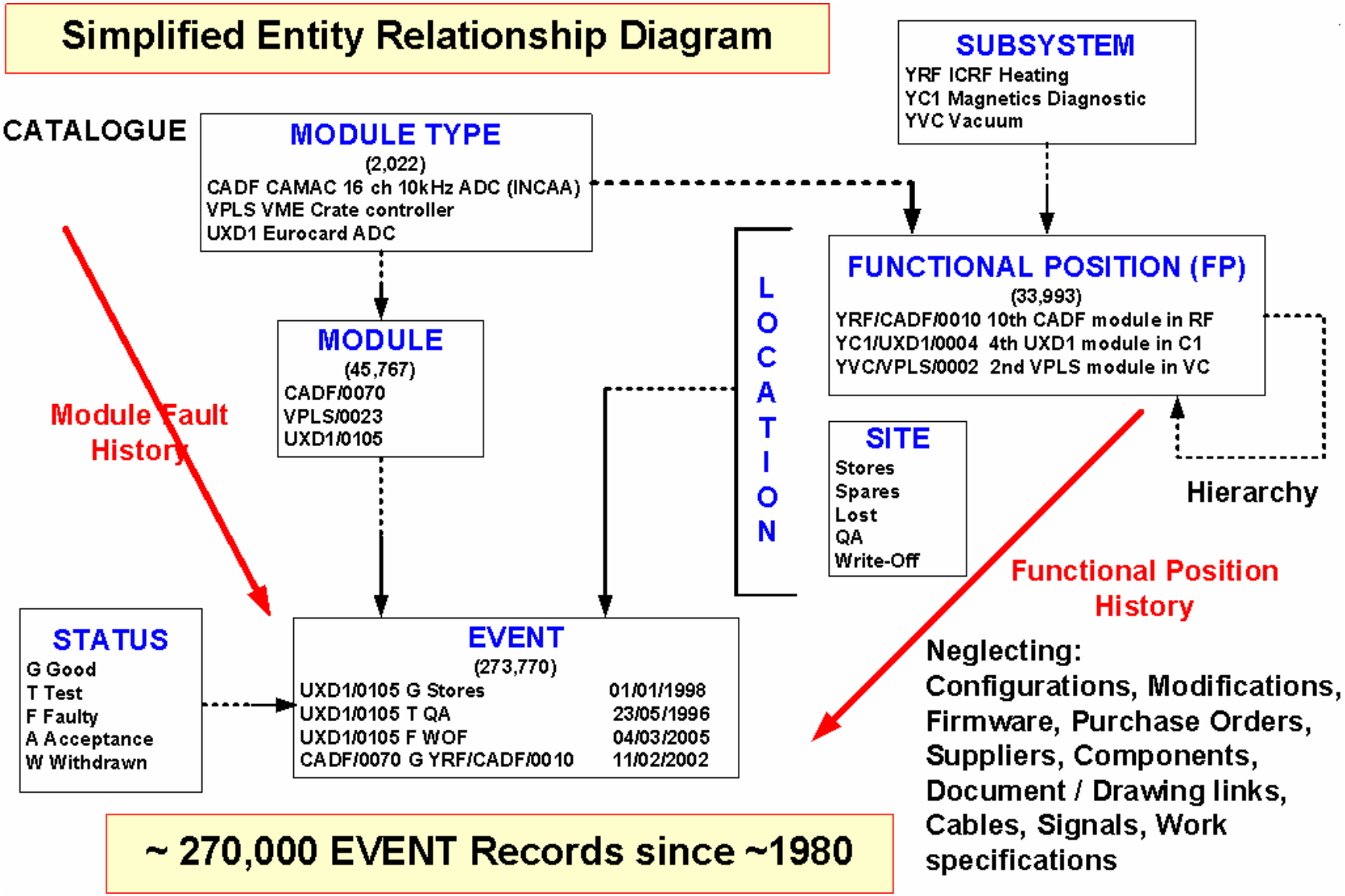
- JET Extension through Framework Programme 7 in Support of ITER
- Shutdown March 2007
  - ITER-like RF Antenna
  - High Frequency Pellet Injector
  - Many diagnostics
- November 2008
  - Plasma Control Upgrade
- June 2009
  - ITER-like Wall (Be)
  - ITER-like Divertor (W)
  - Neutral Beam Power Increase
  - Many diagnostics
- Extra 43GB / pulse in 2010



Modelling storage requirements

1m of ITER integrated burning plasma simulation yields 1TB data?

Electra Database



Module and Functional Position Histories

History of item : CADF/0070

Date / Time	Status	Location	Config	ROMset	Mod	
08/11/2004 14:53:17	Withdrawn	WOF	...	0	E	H384
03/06/2004 15:53:25	Test	MAN	...	0	E	To IN
15/03/2004 14:50:54	Test	JQA	...	0	E	Remo
11/02/2002 15:35:54	Good	YRF/CADF/0010	...	0	E	Repla
17/07/2001 09:32:10	Good	STR	...	0	E	Repla
17/07/2001 09:32:23	Good	YTM/CADF/0001	...	0	E	Redep
10/07/2001 10:51:43	Test	TMP	...	0	E	Modif
09/05/1995 13:13:35	Good	YRF/CADF/0005	...	0	D	
25/11/1994 11:06:22	Good	STR	...	0	D	Passe
25/11/1994 11:06:34	Good	SPA	...	0	D	Upda
23/11/1994 15:45:52	Acceptance	JQA	...	0	D	Ref JX
15/09/1994 09:49:15	Faulty	MAN	...	0	D	Ref JX
20/05/1994 11:40:06	Faulty	JQA	...	0	D	Fails
15/04/1994 07:20:32	Test	JQA	...	0	D	Remo
14/04/1994 17:41:16	Good	YY6/CADF/0001	...	0	D	Dumm
27/08/1993 09:07:33	Good	YY6/CADF/0001	...	0	C	Repla
02/07/1993 09:04:25	Good	STR	...	0	C	Passe
02/07/1993 09:06:08	Good	SPA	...	0	C	Upda
01/07/1993 13:43:55	Acceptance	JQA	...	0	C	Ref JX
20/05/1993 10:58:14	Faulty	MAN	...	0	C	Ref JX

History of functional position: YRF/CADF/0010

Date	Item	Status	Config	Mod	Comment
09/06/1993	CADF/0080	G	...	C	
21/06/1994	CADF/0113	G	...	D	
23/05/1995	CADF/0038	G	...	D	
30/08/1997	CADF/0146	G	...	D	
09/07/2001	CADF/0146	G	...	E	Dummy Mod Leve
12/07/2001	CADF/0002	G	...	E	Redeployed.
11/02/2002	CADF/0070	G	...	E	Replaced suspect
08/01/2005	CADF/0226	G	...	E	Re-deployed.

```
 Func.Posn              Slt  Cnfg R Description
YRF/CCB1/0006           011  BAA  R Crate address 04
.YRF/CFA1/0006          000  ...  R
                        14/11/1997 CFA1/0185 G ...  D    Fo
                            14/11/1997 G YRF/CFA1/0006 ...
                            20/12/2001 T JQA           ...
                            07/06/2002 T JQA           ...
                            07/06/2002 G SPA           ...
                            07/09/2002 G YPF/CFA1/0021 ...
                        20/12/2001 CFA1/0232 G ...  D    Re
.YRF/CPS1/0006          000 HIGH R
                        01/04/1996 CPS1/0242 G LOW  .
                            01/04/1996 G YRF/CPS1/0006 LOW
                            29/06/2002 T JQA           LOW
                            01/07/2002 G SPA           LOW
                            04/07/2002 G YJ3/CPS1/0001 LOW
                        29/06/2002 CPS1/0014 G LOW  .    Re
                        24/01/2005 CPS1/0196 G HIGH .    Up
.YRF/CADF/0010          001 ...  R Also see dwg:6020 dwg:3724 d
                        30/08/1997 CADF/0146 G ...  D
                            30/08/1997 G YRF/CADF/0010 ...
                            09/07/2001 G YRF/CADF/0010 ...
                            12/07/2001 T JQA           ...
                            12/07/2001 G STR           ...
                            12/07/2001 G YE1/CADF/0001 ...
                        09/07/2001 CADF/0146 G ...  E    Du
                        12/07/2001 CADF/0002 G ...  E    Re
                        11/02/2002 CADF/0070 G ...  E    Re
```

Expanded FP History. Follow history of FP and installed modules at any level in the hierarchy

Unusual to have such a detailed audit-trail

Stock Management

Current configurations for itemtype : UXD1

Configuration	State	Description	Parent	MaxSp	MinSp	Notes	Dc
???	C	Undecided		0	0		
AAA	C	Range +/– 250mV, all channels		1	1	Notes	JTS/H
BAA	C	Range +/– 1V, all channels		1	1	Notes	JTS/H
CAA	C	Range +/– 2.5V, all channels		1	1	Notes	JTS/H
DAA	C	Range +/– 10V, 8 channels, 10kHz		4	1	Notes	JTS/H
DAX	C	Differential, +/– 10V, 8 channels, 10kHz		2	1	Notes	Y2/SC
DBA	C	Range +/– 10V, 8 channels, 540Hz		2	1	Notes	JTS/H
DCA	C	Range +/– 10V, 8 channels, 118Hz		1	1	Notes	JTS/H
EAA	C	Range +/– 25V, all channels		1	1	Notes	JTS/H
FAA	C	Range +/– 100V, all channels		1	1	Notes	JTS/H
GBB	C	Range +/– 50mV, 10Hz band, 4 odd Ch only		1	1	Notes	Y2/SC
GCB	C	Range +/– 50mV, 1kHz band, 4 odd Ch only		0	0	Notes	
GCC	C	Range +/– 50mV, 1kHz band, low offset		1	1	Notes	
HAB	C	Current log amplifier, 100pA to 10mA		2	1	Notes	Y2/PC
HZB	C	As HAB but with two monitoring ch's.	HAB	0	0	Notes	Y2/PC

Min, Max number of spares to be held

Stock Summary for itemtype : UXD1

STOCKS	Held:	314	a	Total delivered to date	
	Ordered	0	b	Still Outstanding	
STATUS	Good:	295		Test:	1
	Faulty:	0		Acceptance:	1
	Withdrawn:	17			
LOCATION	Used:	235		In required FPs	
	Recoverable:	16		In non–required FPs	
	Stores:	8			
	Returning Site:	17		Excludes items in stores	
	Non–Returning Site:	17	c	Usually lost or scrapped	
	Person:	0	d	Issued to a person	
SPARES	Spares Held:	20		Minimum:	14
				Maximum:	20 e
ANALYSIS	Requirements:	279	f	Number of required FPs	
	Vacancies:	44		Required FPs, not occupied	
	Excess:	–2		a + b – c – d – e – f	

Components used for itemtype : UXD1

Component	Supplier	Part No.	Bin	Comment	Current Stock
INA114BP INST AMP	FARN FARN	121–2399 846–6742	1C01A5	RoHS Compliant	50
Xilinx 1765EPC PROM			1C02A5		131
XC4003E–4PQ100C FPGA		XC4003E–4PQ100C	1C01B6		3
ADC CS5102A–JL 20KHz	SEQU	CS5102A–JL	1C01B7	last bought Memec	34
INA118P	RS FARN	182–8534 483–126	1Q1801		24
HCPL–7100 CMOS Coupler	KENC	HCPL–7100	1C01B2	Replaced by HCPL7710	96
HCPL–2531 Coupler	KENC	HCPL–2531	1C01B3		49
HCPL–2231 Coupler	KENC	HCPL–2231	1C01B3		50
DG509ACJ Multiplexer	KENC	DG509ACJ	1C02B4	Obsolete	73
AMP OP97EP	ABAC	OP97EP	1C02B5		221
IRLD024 Power MOSFET	RS	189–0488	1C02B9		729
4–way pack	BOUR	4605X–101–121	1R10D6	More stock in 1R15D1	2500
PWS745–4 Trnsfmer 3:1	BURR	PWS745–4	1C02B1	Last bought Kennett	396
PWS740–3 Diode Bridge	BURR	PWS740–3	1C02B3	Unobtainable	88

Spares are different from Stores

Automatic Shortage Reports

```
Obsolete components
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The Burr-Brown PWS745-4 transformers (4 per board) ceased production in 1995
but enough were bought for a maximum of 470 modules (UXD1+UXT1), including
those already built.  Since then the PWS745-1 driver chip (1 per board) and
PWS740-3 diode bridge (4 per board) have ceased production and limit our
future build (ref: order placed with LI-components in June 2005, obtained
25 and 53 pieces respectively).
SED 16.1.2001. updated June 2005
```
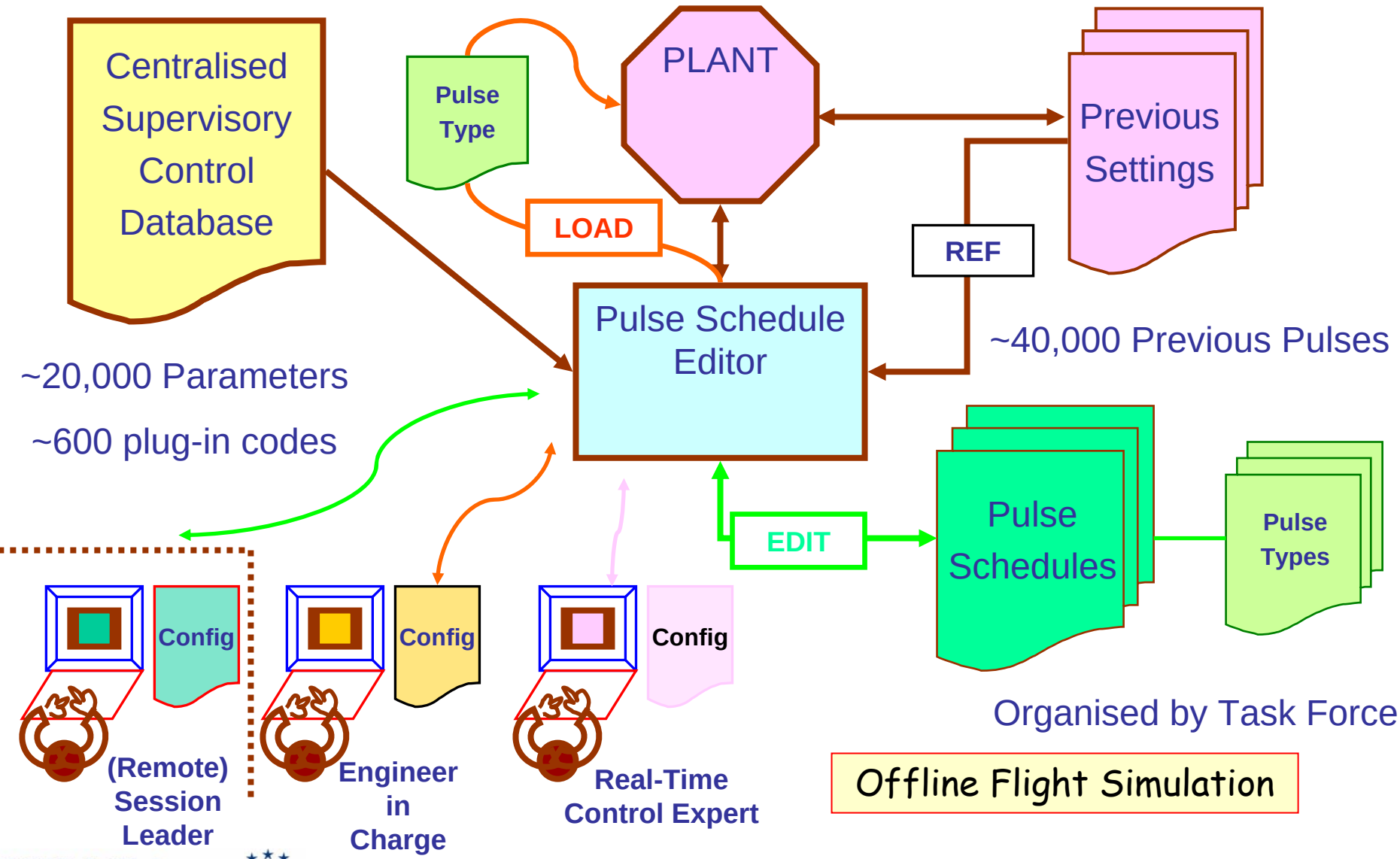
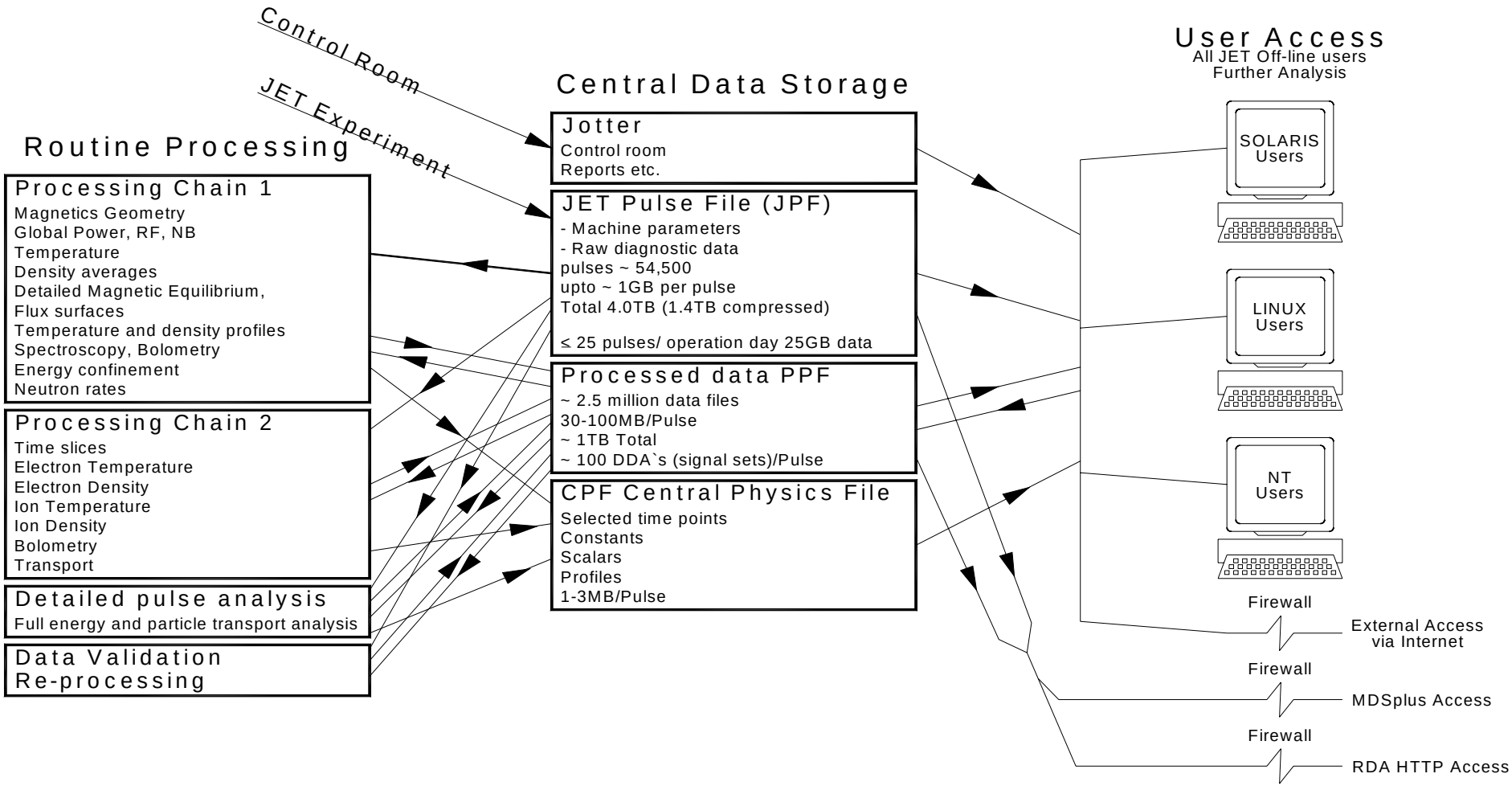

Object Monitoring System (OMS)

plant://pf/tstatus:1 specifies a live-database signal
alarm://mc/alarm-ident specifies an alarm
alarm://mc/alarm-ident?help specifies the *help text* for an alarm
level1:/l1/parameter specifies a Level 1 parameter from the default database
level1://ye/l1/parameter specifies a Level 1 parameter from the YE database
wave://tf/wave-form-name specifies the latest version of a waveform
wave://tf/wave-form-name:version specifies the a particular version of a waveform
udp://sa/ident specifies a *User Defined Point*
level1-array://tf/array-name specifies an array
real-time://pf/point specifies a point from the *Real Time Acquisition* system (for use by applications such as xrtdisp).
file://TF/jet/pf/etc/file Specifies the file /jet/pf/etc/file should be monitored by the OMS server on TF
cfr:number specifies the text of a CODAS Fault Report
jetlog:thing specifies an item in the JET log.
snmp:/command?target specifies an SNMP command to be executed on a particular target
xdc:/ Specifies a complete list of ALL xterminal users
xdc:/mmi-cn1-1 specifies the xterminal users of terminals being managed by mmi-cn1-1
ppf:/ppf-ident-string specifies data from a PPF dataset on the IBM mainframe. It could be a list of signals in the PPF or the data associated with a particular signa

Pulse Preparation – Level-1 Software



JET Data Analysis



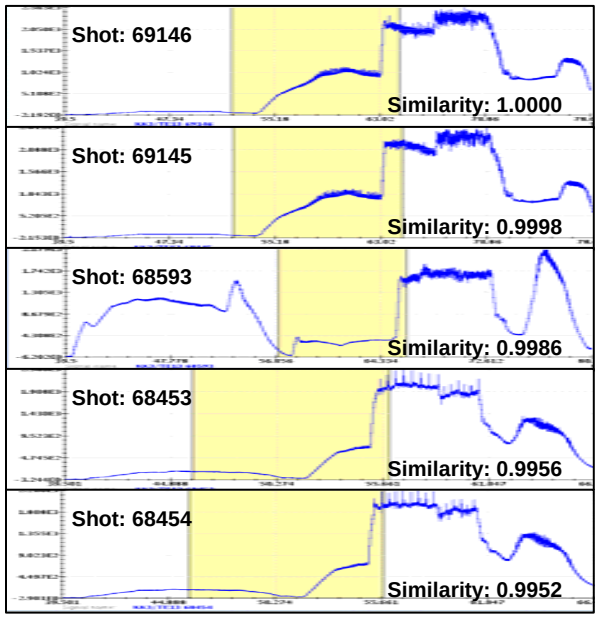
Some of the other JET Databases

- Jet Logging
  - Experiment comments, Fault Logging
- Statistics
  - CPU, Network measurements etc, Capacity planning
- Experimental planning
- Machine configuration
- CODAS Support Databases
  - Cubicle Design/Documentation, Inventory Management, Document Management
  - Product handler – software releases and installations
- Diagnostic Data Handbook
  - Explains the meanings of the measurements
- Solaris Control System
  - NIS
  - Access control database – user, role of user, location of user, state of JET
- IT Systems
  - Account management, Management Systems, Hardware, Software requests, Planning, Maintenance scheduling
- Publications / Pinboard

Not all as integrated as we would like

"Patterns in signals" approach: time-series data. An example in JET

ECE signals: electron temperature



All patterns follow the same behaviour but during different time

- A fall
- A growing slope
  - More abrupt in the 3rd case
- A flat zone
- A fast rise
- A flat top

Plant Systems delivered "in-kind"

- Self-description of the plant systems delivered "in-kind"
  - Cubicles, modules, wiring, signals, software, firmware, history …
  - Merged into centralised CODAC / ITER-wide database
  - Schemas supplied by ITER
  - SQL 2006 Standard - ISO/IEC 9075-14:2006 – Merges SQL and XML

- Single plant and signal naming scheme
  - Rules to be developed
  - Universal Resource Identifiers (URIs). See RFC 3986
  - http://www.iter.org/ns/ ns=namespace
  - Qualified Names or Qnames
    - e.g. signal: = http://www.iter.org/ns/signal/
    - signal:neutrons/14mev_neutron_flux
  - URL equivalent of URI gives meta data access
    - Access to data as appropriate