Integrated Data Acquisition, Storage and Retrieval for Glass Spherical Tokamak (GLAST)

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Outline

- Introduction to GLAST
- Systems & Diagnostics
- Evolution of Data Acquisition System
- Future Directions of GLAST Data Acquisition & Control System

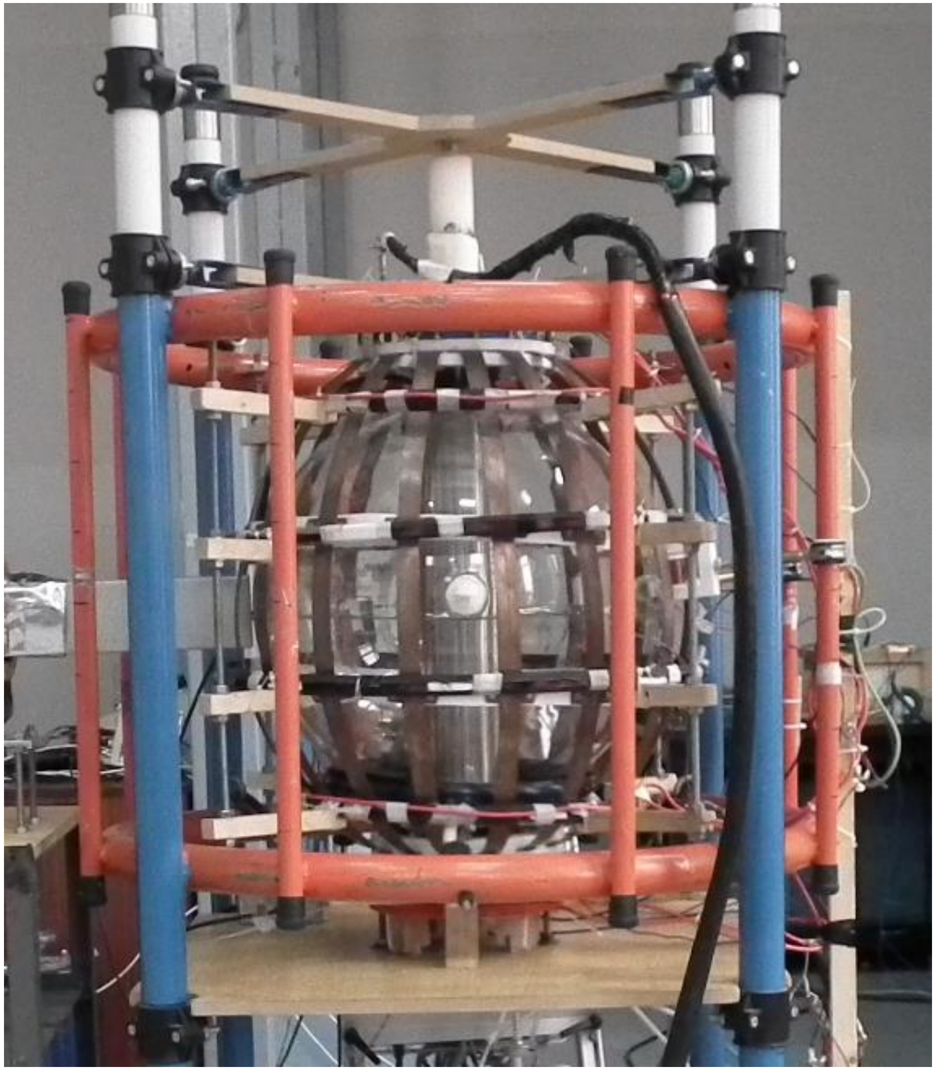
Introduction

GLAss **S**pherical **T**okamak (GLAST) is a series of small Spherical Tokamaks with an insulating vacuum vessel of major and minor radius as tabulated below:

	Major Radius (cm)	Minor Radius (cm)
GLAST I	15	9
GLAST II	15	9
GLAST III	20	10

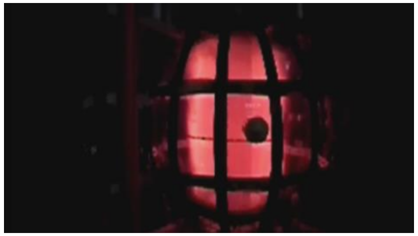
GLAST I

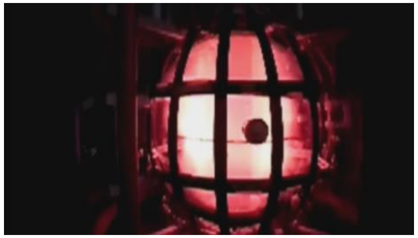
- Steel pipe at center
- Chamber dia. = 50 cm
- Aspect ratio = 1.5

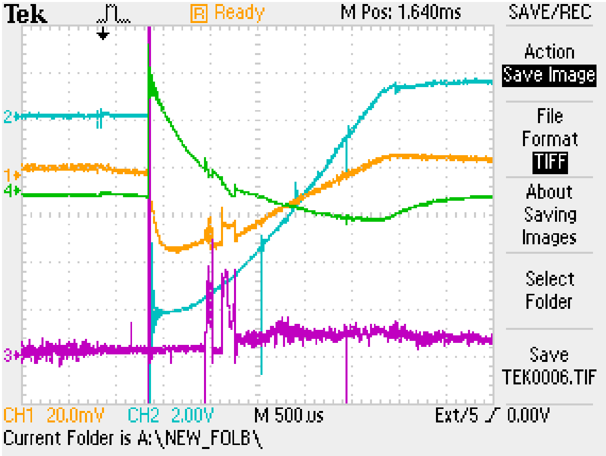


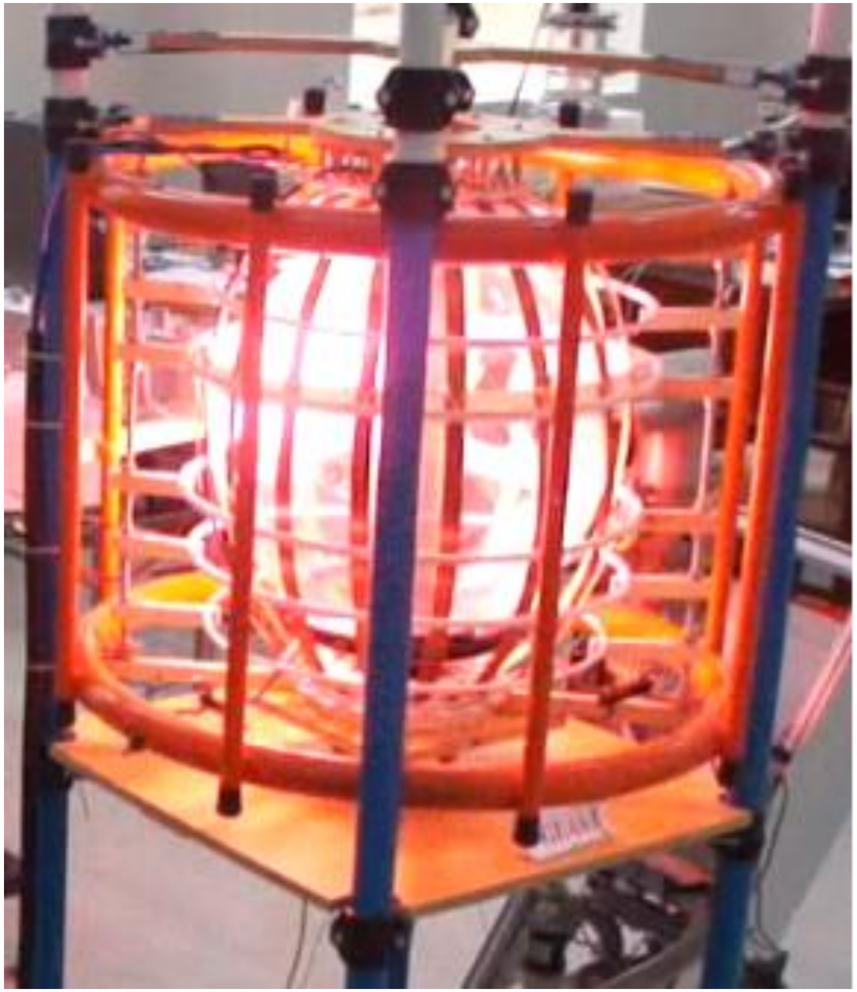
GLAST I

- Neon Gas Pressure = 3 micro bar
- Frame Rate = 480 fps
- Total Discharge Time = 8msec



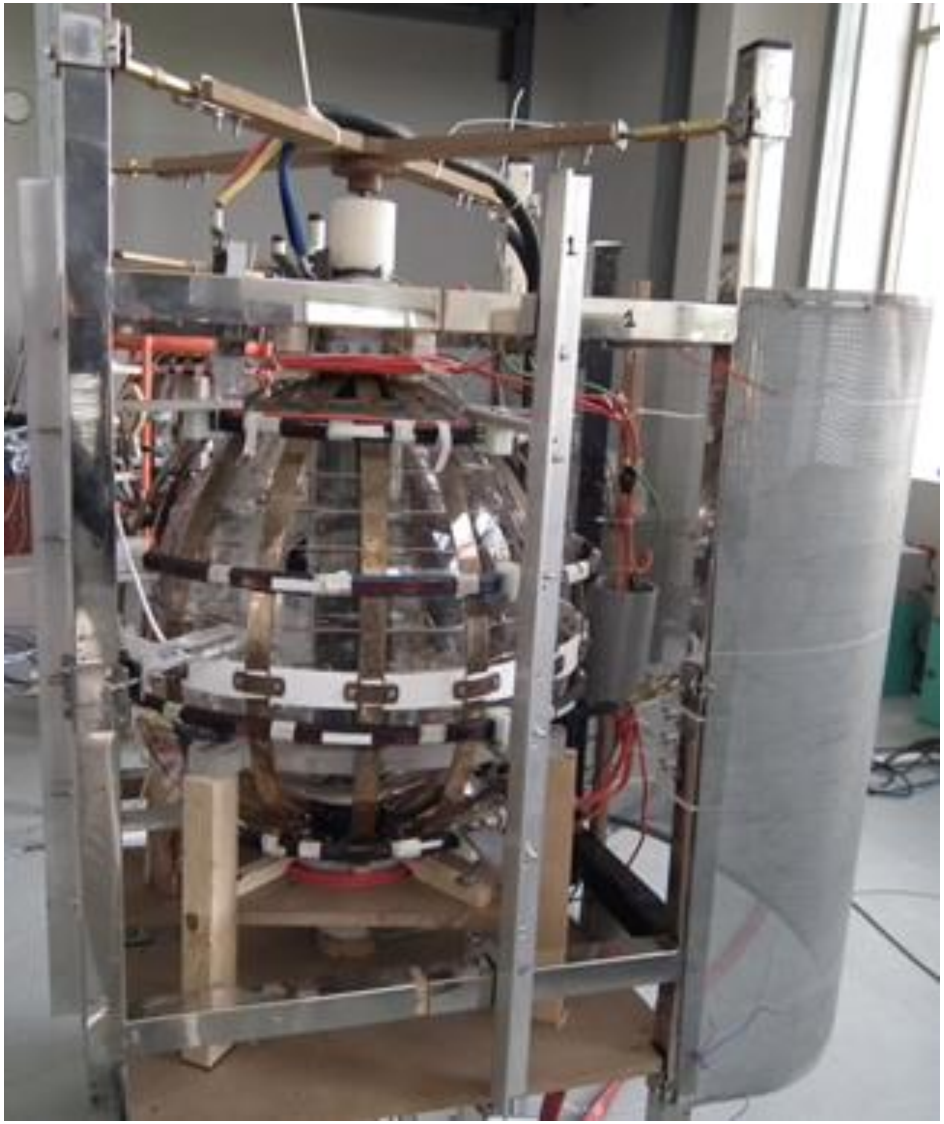




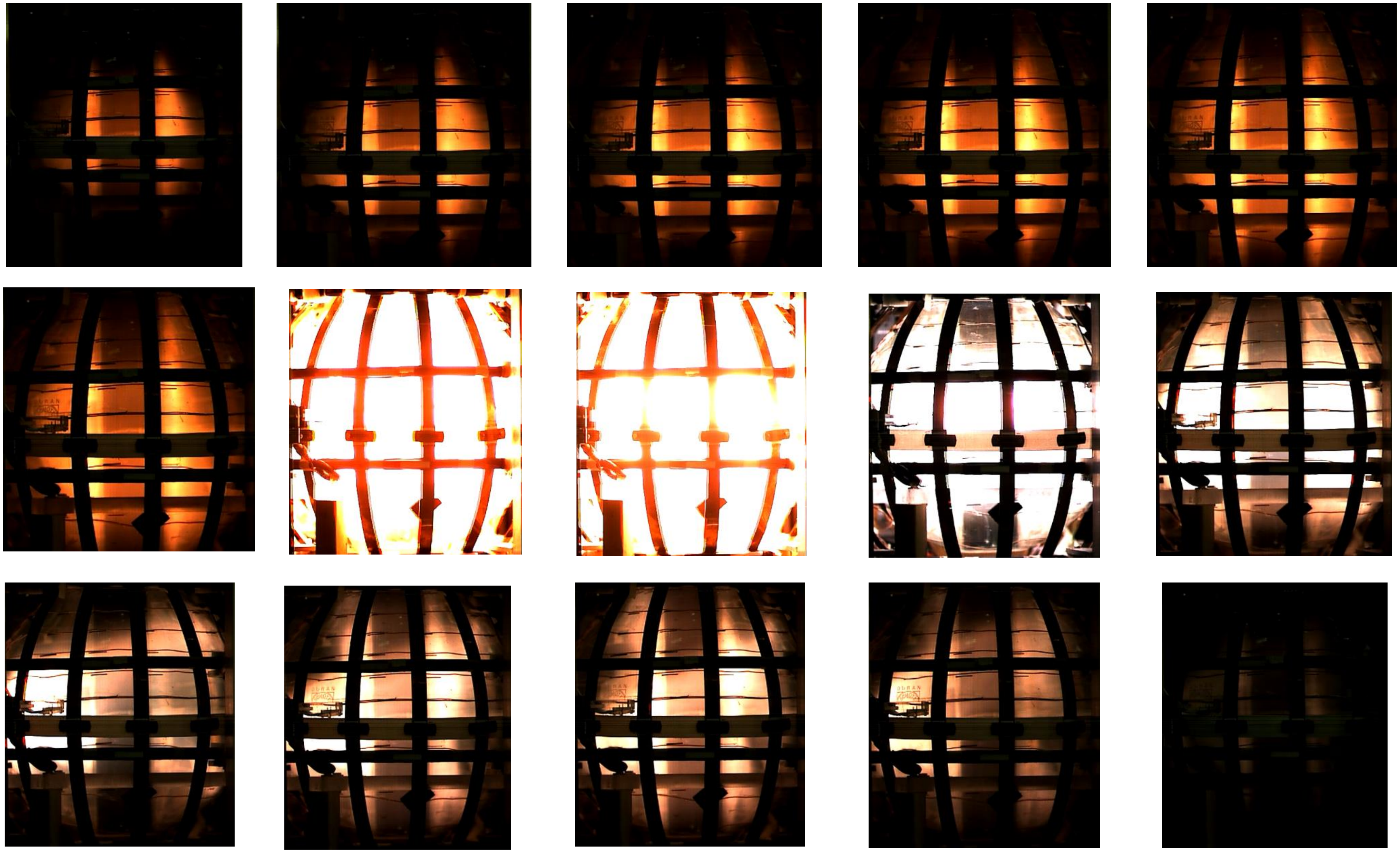


GLAST II

- Glass pipe at center
- Chamber dia.   = 50 cm
- Aspect ratio   = 1.6



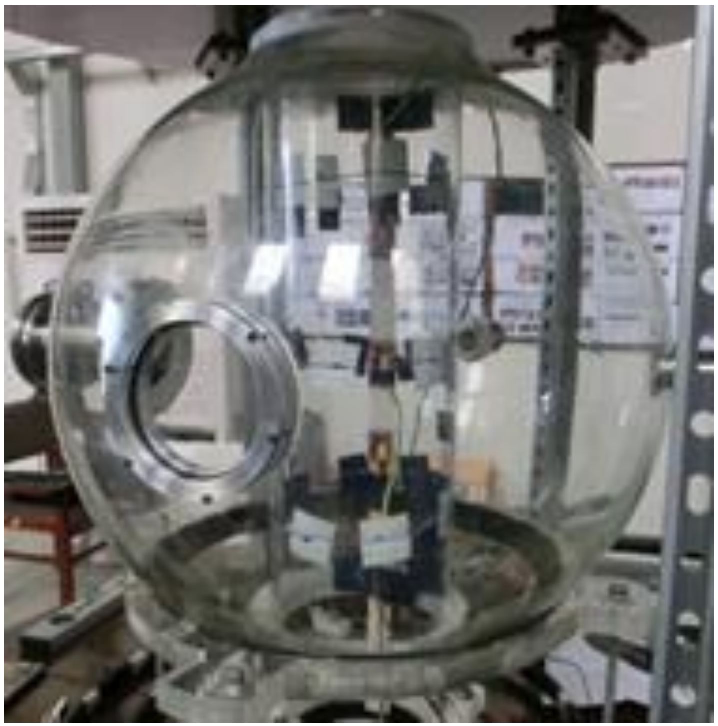
Temporal Formation of Plasma in GLAST II

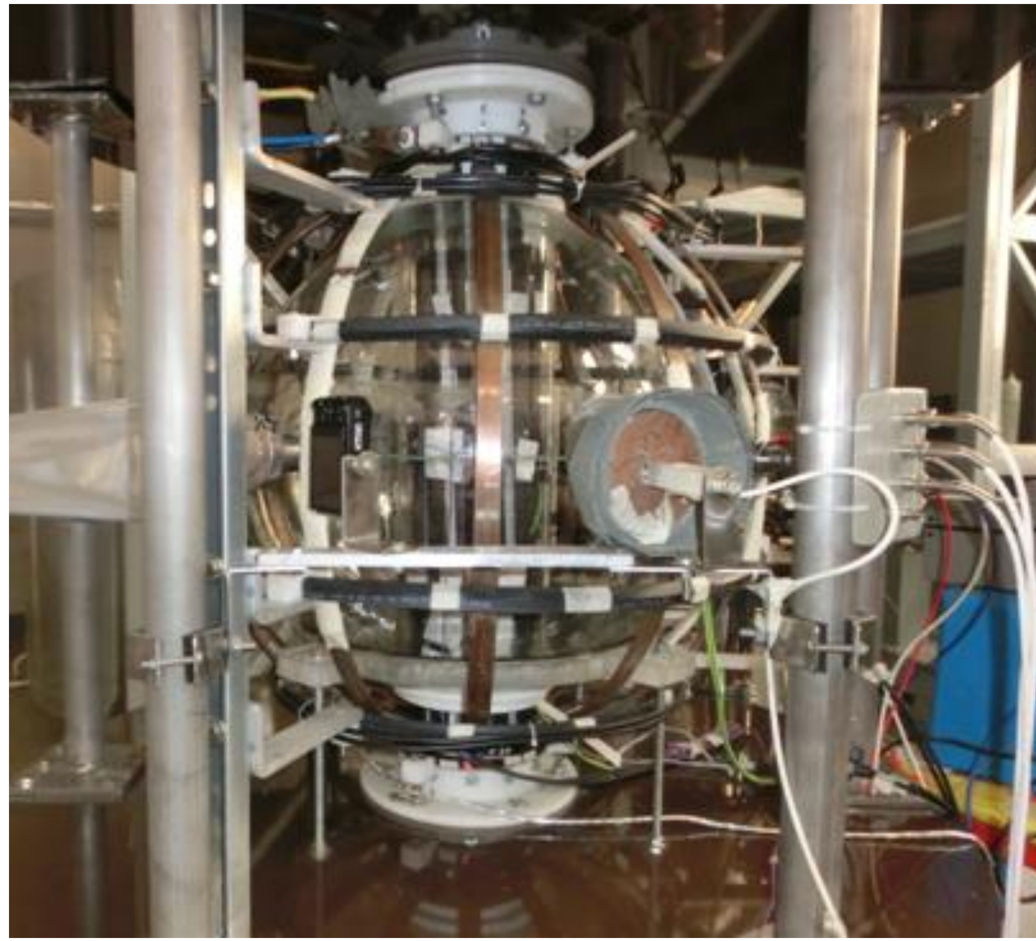


5k fps (1 Frame = 0.2msec)

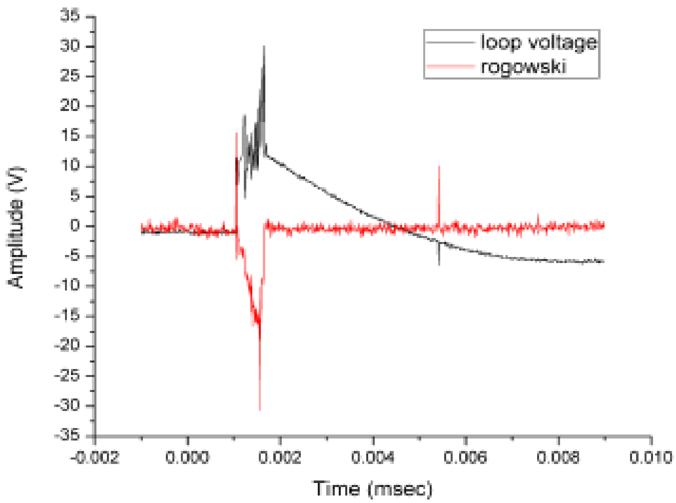
GLAST III

- Glass pipe at center
- Chamber dia. = 60 cm
- Aspect ratio = 2





Plasma formation in GLAST III



Plasma Current = 5-7kA for 1msec

GLAST Systems

- Power Supply System

To energize different magnetic coil systems and microwaves

- Microwave System

- Magnetic Coils System

Toroidal Field Coils System, Central Solenoid Coil System, Poloidal Field Coil System

GLAST Systems

- Glow Discharge Cleaning (GDC) System

- Timing Center & Trigger System

On site developed system for synchronized & precise triggering of different capacitor banks and instrumentation.

It has been developed using PIC-18F4550 Microcontroller.

- Data Acquisition System

GLAST Diagnostics

- Electromagnetic Diagnostics

  Rogowski coils, Magnetic probes, Plasma flux loops etc.

- Plasma Diagnostics

  Langmuir probe, Rack probe, Spectrometers, Photo diodes etc.

- Plasma Imaging

  Using High Speed Camera (Photron SA-8, 30k fps)

- Residual Gas Analyzer (RGA)

DAQ Requirements of Diagnostics

The table below shows different transducers & systems which require a reliable data acquisition system for the measurement of stated parameters.

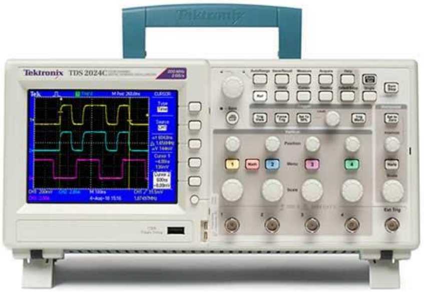
Parameters being Measured	Signal Transducers/ Sources
Plasma Current	Rogowski Coil (Developed on site)
Magnetic Fileds	Magnetic Probes
Loop Volts / Differential Loop Volts/Plasma Position	Flux Loops
TF, CS and VF Currents	LEM Current Transducers
Microwaves Intensity	RF Diodes and Network Analyzer
Light Intensity	Photo Diode
Electron Temperature and Number Density	Langmuir Probe
Plasma Imaging	High Speed Camera (SA-8)
Concentration of different gasses in vacuum vessel	RGA

Oscilloscopes based DAQ System

Just like any other research lab, NTFP started with:

- Tektronix TDS Series Oscilloscopes

12 Channels (from 3 Oscilloscopes) were used to acquire the data from very basic diagnostics.



There were many shortcomings regarding the pre-shot & post shot activities using this data acquisition technique.

- Tektronix MSO Series Oscilloscopes

were included in that prevailing system to automatically save the acquired data and perform some basic and advance mathematical operations on the acquired waveforms.
It also comprised of 3 Scopes (12 Channels).

Comparison b/w DAQ cards & Oscilloscopes

The oscilloscopes are not a complete DAQ solution for such experiments. There is a need of DAQ cards for this purpose.

Data Acquisition Cards	Oscilloscope
Large number of input channels (4-32)*	Very few channels (1-4)
Analog Outputs	N/A
Varying input voltage range	Fixed input voltage range
Programmable gain	No Programmable gain
Programmable CMRR	No CMRR
Digital and Analog Acquition	Analog Acquisition
High Throughput (MS/s)	Low throughput (MS/s)
High level customization	N/A

DAQ Systems of Different Tokamaks

DAQ System	Tokamaks
USB	GLAST, GOLEM
VME	ISTTOK, SST1, KSTAR, KTM
PCI	EAST, ISTTOK, COMPASS, HT-7
PXI	ITER, SST1, COMPASS, KSTAR, GOLEM

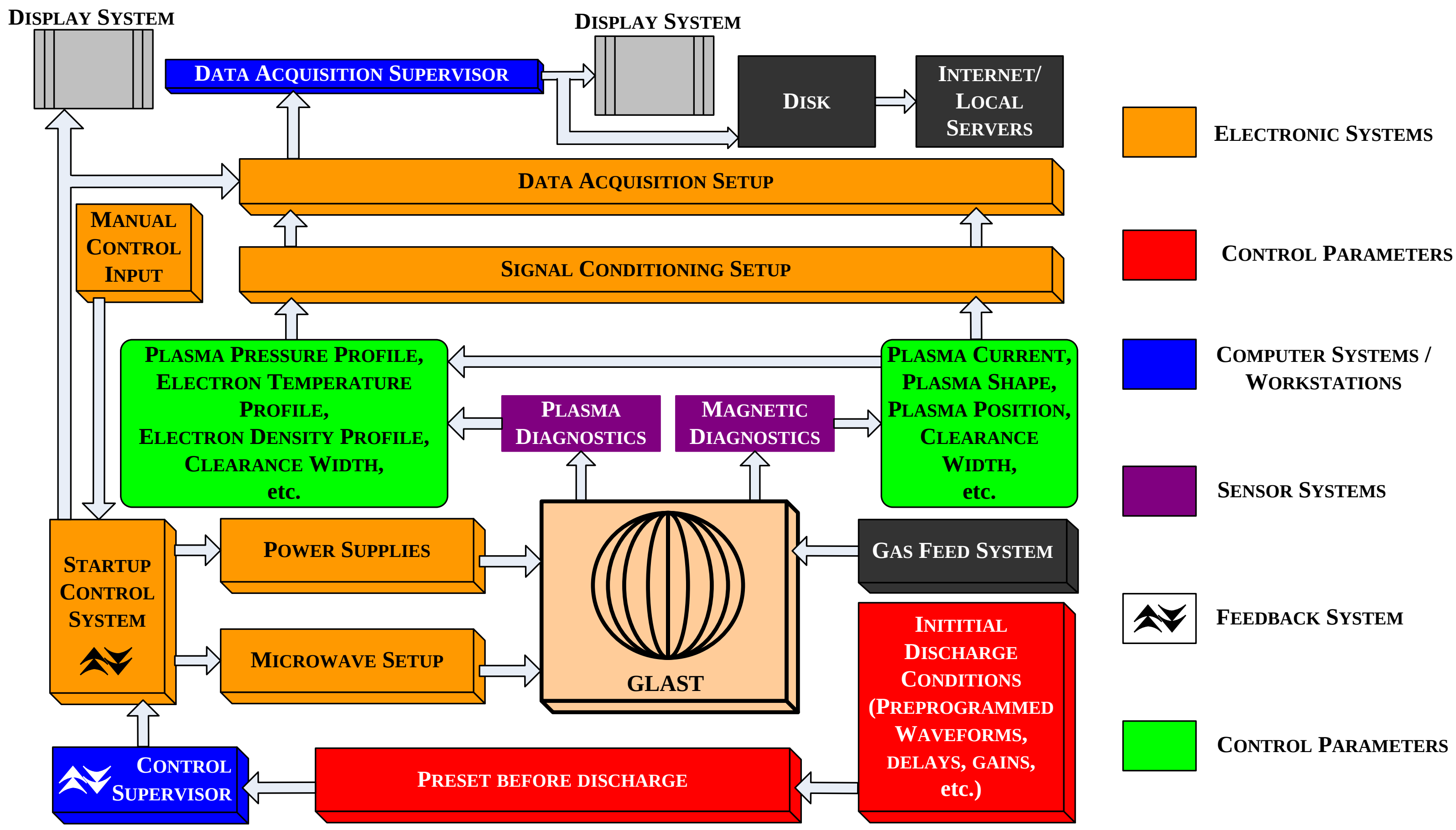
NI DAQ cards based DAQ for GLAST

- National Instruments Data Acquisition Cards (NI-USB 6363) have been successfully added in that system.

Specifications of NI-6363 USB X Series DAQ Card

Number of Channels	16 Differential (or 32 Single ended)
ADC resolution	16 bit
Sample rate	2MS/s (single channel max) 1MS/s Multichannel (Aggregate)
Time Resolution	10ns
Input Range	±10V
Data Transfer	USB
Overvoltage Protection	±25V (Device:on) & for up to 2 AI pins ±15V (Device: off)

Data Acqusition and Control System of GLAST



Data Acqusition (DAQ) System of GLAST

DAQ Hardware includes:

- Signal Conditioning Modules
- DAQ Card (16 Differential Channels @ 100 kS/sec)
- DAQ PC
- Data Storage System (with RAIDs)

DAQ Software comprises of

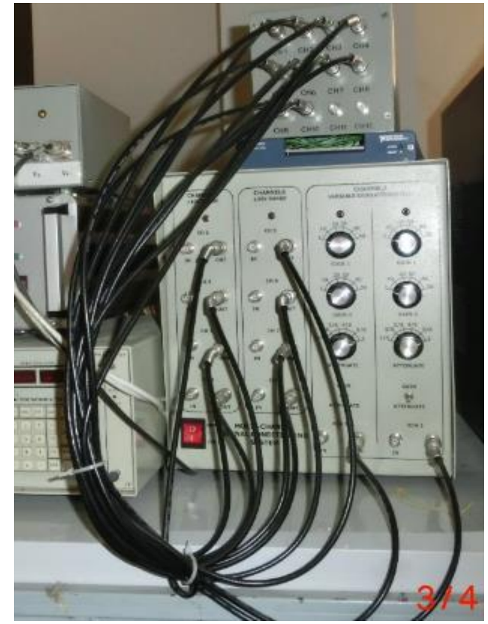
- LabVIEW
- Matlab

for front and back end handling.

Signal Conditioning (SC) Module

An on-site developed signal conditioning modules are responsible for:

- Buffer / Gain / Attenuate the incoming analog voltage input signals from different diagnostics and systems.
- These modules bring the incoming signals into range of ± 10 V.
- It comprises of
  - 16 Fixed Gain Channels
  - 02 Variable Gain Channels
- Texas Instrument's OPA-637 are the integral part of these signal conditioning modules.



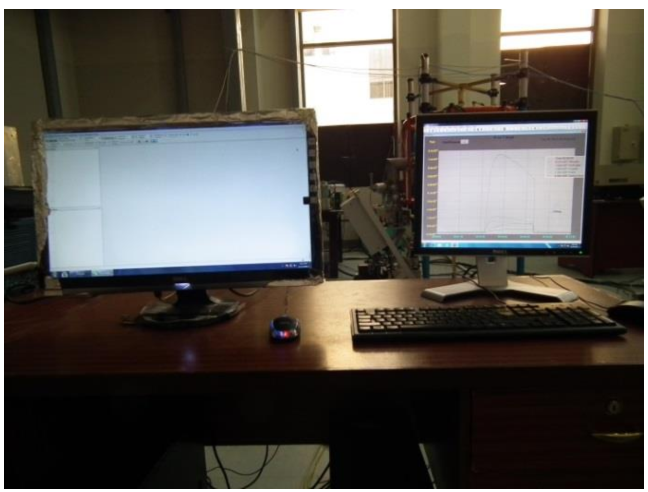
10 Channel SC Module

8 Channel SC Module

Pictorail View of DAQ System @ GLAST

12 Channel from Oscilloscopes

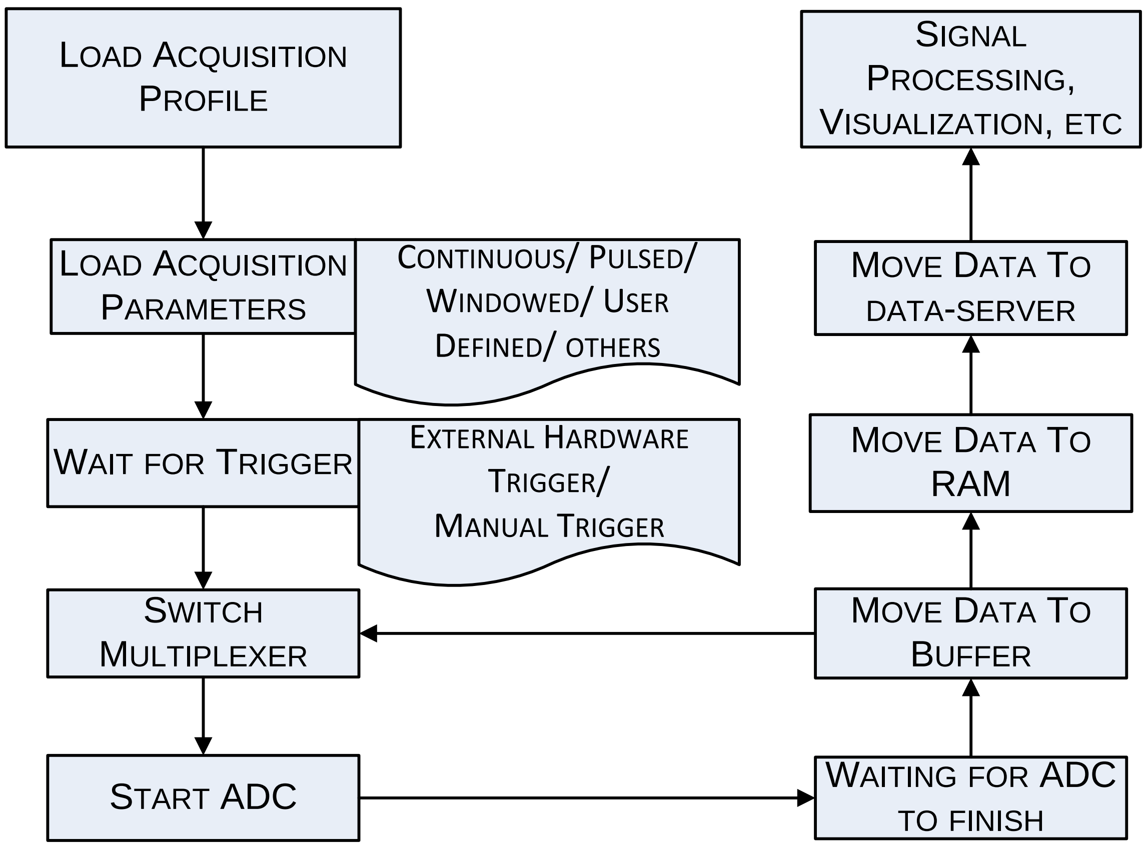
16 Channel DAQ System



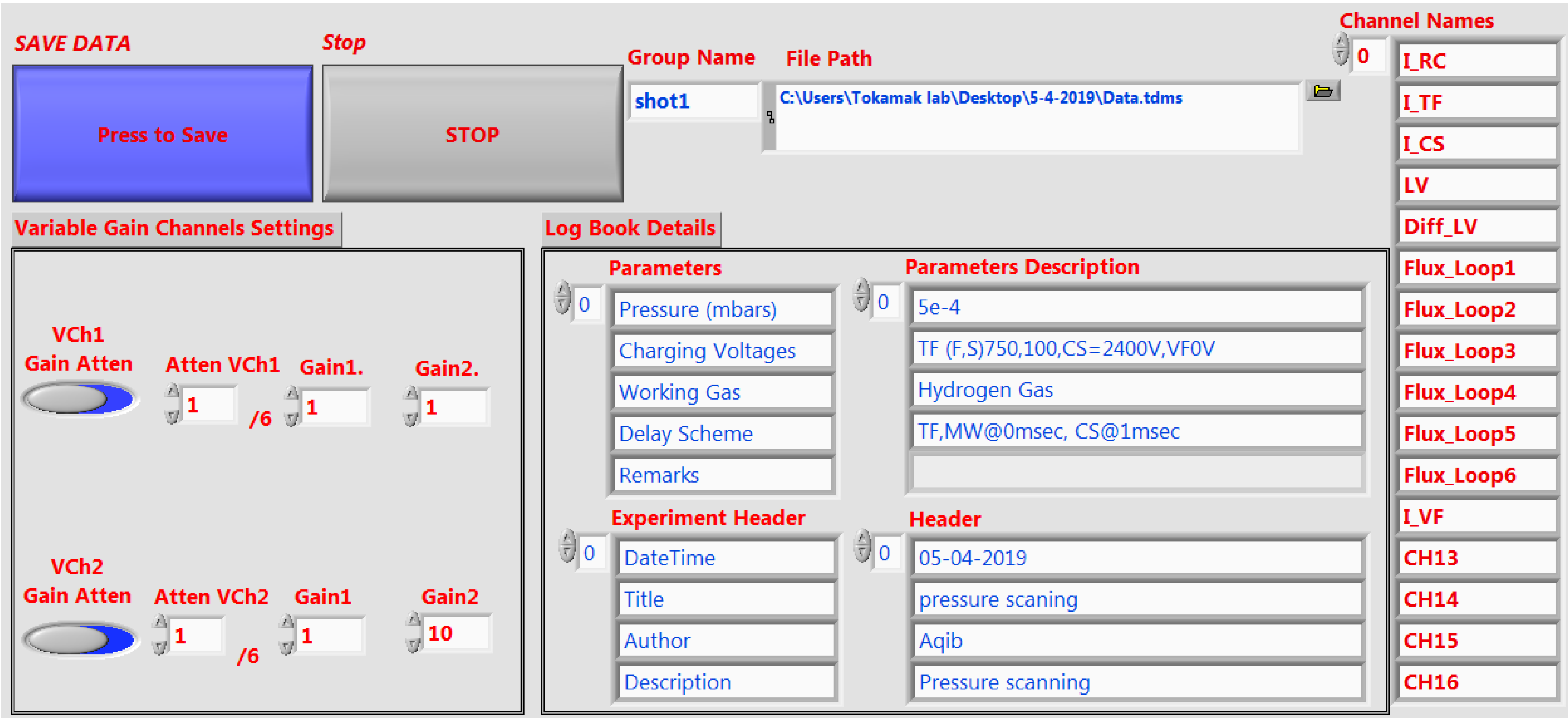
Control Panel

Display Panel

Acquisition Cycle



Acquisition Profile (Configurator)



Storage

- National Instruments has introduced Technical Data Management Streaming (TDMS) in LabVIEW for the purpose of logging the measurement data.

- GLAST DAQ system uses the same format to save the acquired data.

- TDMS file contains two types of data:
  1. Meta Data
  (It contains the information about the channels, their properties and properties of groups etc. The same serves as the log book of GLAST experiments).
  2. Raw Data
  (It contains the actual data from all DAQ channels)

Storage

Meta Data

1	**Root Name**	**Title**	**Author**	**Date/Time**	**Groups**	**Description**	
2	Data	pressure scaning	Aqib	05/04/2019 12:00:00.000 AM	12	Pressure scaning by using TF, CS and hydrogen gas	
3							
4	**Group**	**Channels**	**Description**	*Charging_Voltages*	*Delay_Scheme*	*Pressure*	*Working_Gas*
5	shot1	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	Vacuum Shots	No Gas
6	shot3	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	1 exp -4	Hydrogen Gas
7	shot4	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	2 exp -4	Hydrogen Gas
8	shot5	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	3 exp -4	Hydrogen Gas
9	shot6	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	4 exp -4	Hydrogen Gas
10	shot7	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	5exp -4	Hydrogen Gas
11	shot8	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	6e-4	Hydrogen Gas
12	shot9	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	7e-4	Hydrogen Gas
13	shot10	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	8e-4	Hydrogen Gas
14	shot11	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	9e-4	Hydrogen Gas
15	shot12	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	1e-3	Hydrogen Gas
16	shot13	16		TF (F,S)750,100,CS=2400V,VF0V	TF,MW@0msec, CS@1msec	2e-3	Hydrogen Gas
17							

Raw Data

1	**I_RC**	**I_TF**	**I_CS**	**LV**	**Diff_LV**	**Flux_Loop1**	**Flux_Loop2**	**Flux_Loop3**	**Flux_Loop4**	**Flux_Loop5**	**Flux_Loop6**	**I_VF**
2	53.34377846	20.26231552	-9.842711316	-0.03339242	-0.021799562	-0.010164735	-0.004046283	-0.005012354	-0.006622473	-0.007588545	-11.13488155	-79.57642547
3	56.56401659	19.87588702	-9.52068749	-0.031460277	-0.019867419	-0.010486759	-0.004046283	-0.004046283	-0.007266521	-0.007266521	-11.13488155	-70.36651242
4	59.78425473	19.87588702	-9.842711316	-0.032426348	-0.017935276	-0.010486759	-0.004046283	-0.00469033	-0.006300449	-0.006944497	-11.13488155	-61.09219846
5	581.4629607	-134.6956042	-4.046282603	5.594893212	0.357866297	5.230339279	5.335314854	-5.097309754	4.708036521	-5.225482488	-11.13488155	-3.127828068
6	7959.057934	24.5130289	-23.36771286	10.4396328	0.250632473	5.20393437	5.348517299	-5.357197903	5.316638223	-5.573288956	-11.13488155	-6.992114536
7	13890.7988	24.5130289	-17.24925957	9.925697063	0.500844674	5.558468244	5.727845665	-5.721107178	5.710457116	-5.88277362	-11.13488155	-8.859853244
8	18473.27023	21.80802949	-15.96116418	11.69742032	0.364628789	5.816398436	6.034077068	-6.042186086	6.036653145	-6.23637991	-11.13488155	-8.409019748
9	21867.46914	24.12660041	-6.944496921	11.59598598	0.583926675	5.960980869	6.197335876	-6.190971359	6.180591389	-6.35682542	-11.13488155	-8.795448459
10	23976.77353	16.39803051	2.716217168	12.32051651	0.484421485	6.085276591	6.360594545	-6.366164786	6.351256282	-6.527510569	-11.13488155	-8.280210179

Retreival

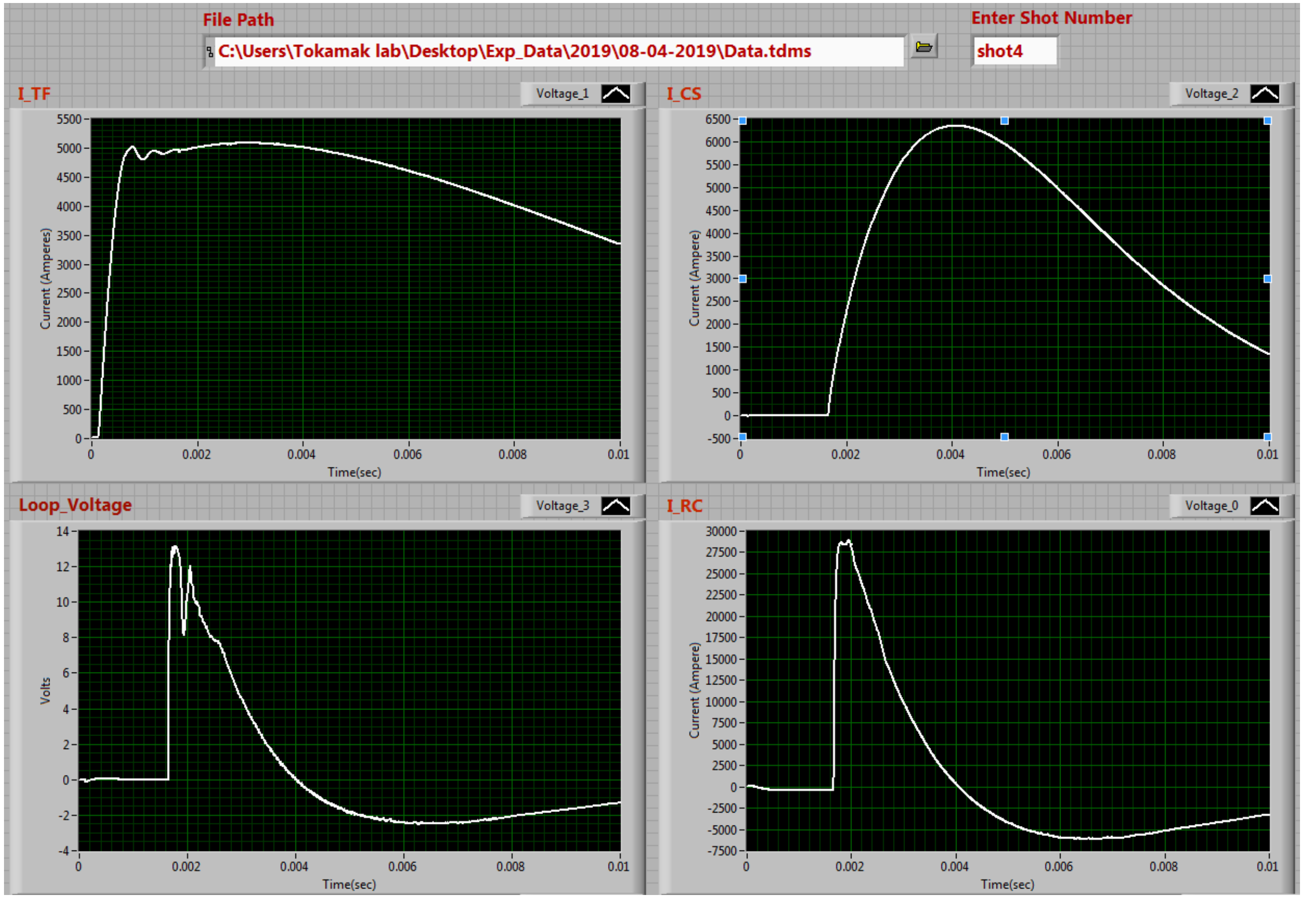
- A dedicated GUI (LabVIEW based) has been developed to:

  1. View graphical representation of experimental shots.
  2. To acquire data for post processing.

- This GUI also provides the Matlab based utilities for data analysis, i.e., numerical integration of the magnetic diagnostics data.

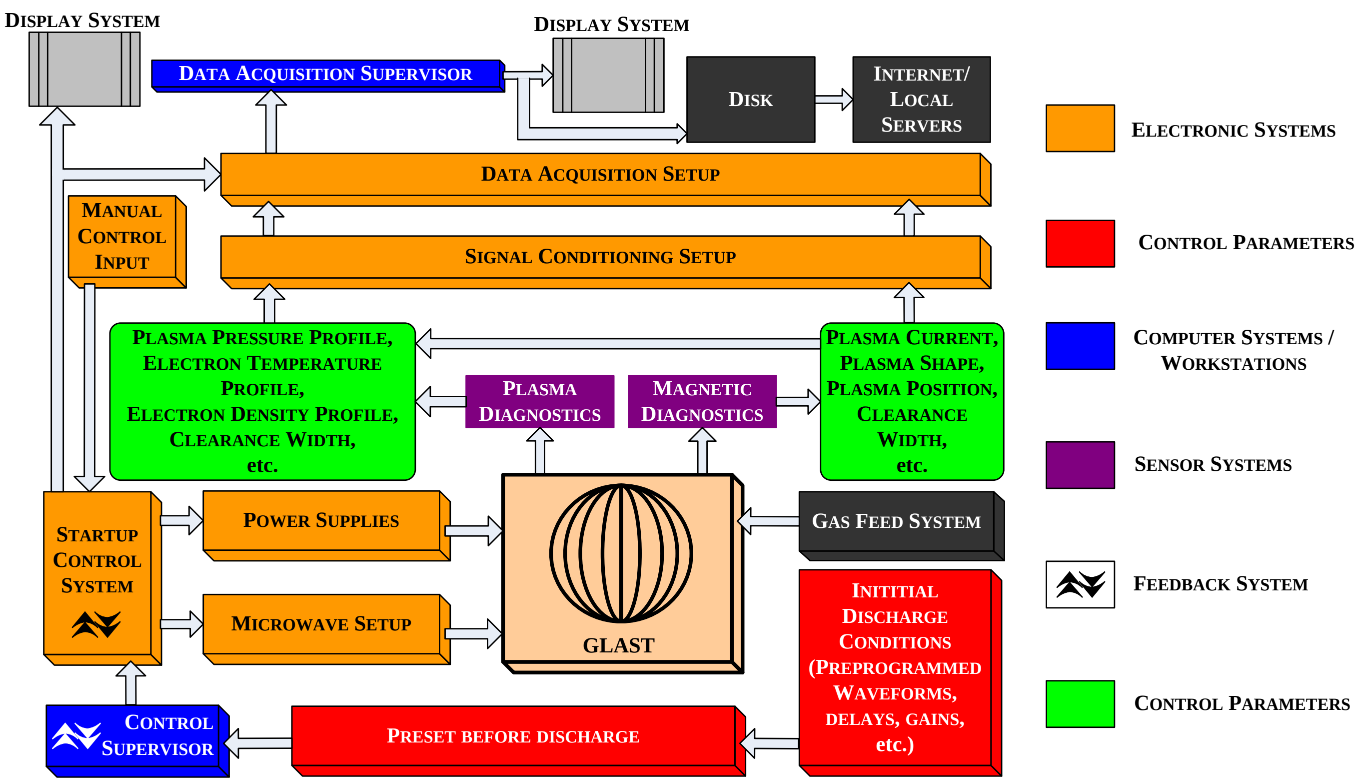
Retreival

A dedicated VI has been developed to retrieve and display data of a particular shot and basic mathematical operation can also be performed on this “Data Viewer VI”.



Future Directions of DAQ & Control of GLAST

- Experimental Physics & Industrial Control System (EPICS) based experimental control facility for GLAST Tokamak.
- Remote Operation of GLAST Tokamak with a single operator interaction.



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