# BaBar Online Detector Control

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**Abstract**

The BaBar Online Detector Control system is described, including the C-based Experimental Physics and Industrial Control System implementation, the C++ interface to the rest of the Online system, and the use of object-oriented databases. Operational experience during the commissioning and 1999 data run is summarized.

Keywords: SLAC,PEP-II,BaBar,EPICS,controls,Objectivity

## 1 Introduction

The BaBar detector is designed to study $CP$ violation in the decays of $B$ mesons produced in asymmetric $e^+e^-$ collisions at the recently commissioned SLAC PEP-II storage ring. High luminosity ($> 10^{33}\mathrm{cm}^2 s^{-1}$) is required to compensate for the small branching fractions ($10^{-4} - 10^{-6}$) of the relevant decay modes. BaBar must exploit this luminosity by maximizing the quantity and quality of recorded data. In addition, the precision nature of $CP$ asymmetry measurements requires datataking under known, stable operating conditions to control and understand the systematic uncertainties.

The primary function of the Online Detector Control (ODC) system is to provide efficient control of the detector operating parameters (high voltage, gas systems...) and real-time monitoring of environmental conditions (temperature, humidity, pressure...) to ensure safe and reliable operations. However, the control system also plays an important role in ensuring the quality of data by providing the rest of the Online system with information on the status of the detector, and by providing PEP-II with information on the amount and nature of the machine backgrounds. Details of the control system have been presented elsewhere [1]. In this paper we give a general description of the major components and then summarize our operational experience with the system during the commissioning and 1999 data run.

## 2 Detector Control and Monitoring

The Experimental Physics and Industrial Control System (EPICS) [2] is used to control and monitor the detector subsystems, environmental conditions, and accelerator parameters. EPICS is a freely distributed software package that includes a real-time kernel running under the VxWorks operating system, drivers for commonly used hardware components (*e.g.*, CAEN, CANbus), and a suite of user applications for control, monitoring, and data analysis. The source code is C and is available for customization by the user. The EPICS architecture is distributed, with the Input/Output Controller (IOC) as the fundamental component. BaBar employs a network of 15

IOCs (Motorola mv177 cpu embedded in a standard VME module) containing $\sim 10^5$ hardware and software channels describing the status of the detector subsystems and central systems infrastructure (Electronics House, Gas Shack, Interaction Hall). Data is updated at rates from a few Hz to once per hour, depending on the channel.

### 2.1 Interaction with BaBar shift crew

Easy access to the detector status is essential when the shift crew typically does not have expert knowledge of the system. The BaBar shift crew interacts with the ODC system primarily through the graphics-based Display Manager (DM) and Alarm Handler (ALH) applications; both available with the standard EPICS installation. DM provides a graphical user interface for push-button control and monitoring of the detector, with a common screen design and alarm color scheme across all subsystems. ALH presents the shifter with an overview of the alarm status of all channels in the form of point-and-click navigation through a hierarchical tree. Both applications have been customized to add user-friendly features not available in the default versions.

### 2.2 Interaction with PEP-II

Close communication between BaBar and PEP-II is critical to maintaining high operational efficiency and low background conditions. Before injection can begin BaBar must be in a safe state (lowered voltages) and it must remain in a safe state until injection is complete. This injection sequence is coordinated automatically by two state machines. One process, running on a BaBar EPICS IOC, verifies and communicates the safe status of the detector to a second process running on a PEP-II IOC that controls beam injection and tuning. Using the same IOC link, the ODC system provides continuous feedback to the PEP-II controllers concerning the level and nature of machine backgrounds before, during, and after injection. This information is used to minimize backgrounds and therefore maximize the quality of data being recorded by BaBar.

## 3 Interface to Run Control

Run Control is responsible for coordinating the various components of the Online system and is the interface used by the shift crew to take data. ODC provides early warning of changing conditions and the chance to prevent bad data from being recorded, saving both time and resources. Integration between these two systems is necessary to fully exploit information about the status of the detector. A dedicated object-oriented interface, the Component Proxy, has been designed to provide an abstraction of the detector components in terms of C++ objects that fills the gap between the C-based EPICS software and the rest of the Online.

Each logical component of BaBar (tracker, calorimeter, etc.) is represented by one or more instances of the Component Proxy, where the specific set of EPICS channels associated with each proxy is configurable from a text file. Each proxy reports the status of its associated hardware component to Run Control in the form of a `RUNNABLE` flag. The exact definition of each flag (implemented at the EPICS level) varies by subsystem, with the general specification that a detector is `RUNNABLE` only if it is ready to take high quality physics data. Run Control is not allowed to begin a data run until all components are `RUNNABLE` , and if a system loses its `RUNNABLE` status during datataking, Run Control automatically pauses the run until favorable conditions are restored. The response time of this feedback mechanism is typically $< 1$ second, varying with the update frequency of the channels used to define the flags.

## 4 Use of Object-Oriented Databases

BaBar has implemented an object-oriented database, Objectivity, to store the $> 100\,\mathrm{TB}$ of event data expected each year. Although alternative technologies exist to satisfy the needs of the Online system, Objectivity was also chosen as the storage technology for detector controls, calibration, and configuration data. This choice allows event and conditions data to be accessed with the same tools while making efficient use of limited human resources. (See Ref. [3] for a detailed description of BaBar online databases).

### 4.1 Ambient data

Access to the time history of detector control (ambient) data is essential in debugging hardware problems, monitoring the health of the detector, and in understanding long-term trends in detector performance. At BaBar, archiving of ambient data is coordinated by the Component Proxy, which monitors EPICS data and transmits it to an Archiver coprocess as CDEV data. The Archiver accumulates the data in a live cache (shared memory) before writing it into the Ambient database. To reduce the amount of database activity, the Archiver "flushes" the cache only once per hour. BaBar is currently running 27 proxies (each with its own archiver coprocess) on two dedicated Sun ULTRA 10 workstations with a total of $.75\,\mathrm{GB}$ ($2\,\mathrm{GB}$) of real (virtual) memory. Combined, the archivers write the equivalent of $2\,\mathrm{MB}$/hr to the Ambient database.

The Database Group has provided several utilities for accessing ambient data. For online browsing and quick access to data spanning a relatively short time interval (up to a few hours), a Java-based online browser has been developed. Two servers use CORBA to transfer data to the browser from either the Ambient database or directly from the Archiver's cache. The browser provides a graphical user interface with a hierarchical directory tree side-by-side with the plotting window. For analysis of long-term data trends and correlations, a second application is available for creating time-ordered ntuples, where time correlation of asynchronous data is accomplished by averaging over a user-specified bin size. In the future, Java Analysis Studio [4] will be used to combine the features of both applications, and to allow explicit correlation between ambient and event data.

### 4.2 Configuration data

Before datataking begins, Run Control initiates a `CONFIGURE` transition by sending a (runtype-dependent) configuration key to the data acquisition, trigger, and detector controls systems that is used to read data from the Configuration database. In the case of detector controls the key is received by the Component Proxy which then reads the data (typically high voltage setpoints) and writes it to EPICS. This system allows for easy switching between run types (physics, cosmics, etc.), and creates an archive of detector configurations in the database that can be used to determine the running conditions at any time in the past.

## 5 Operational Experience

The individual components of the ODC system were installed at the IR between Fall 1998 and Spring 1999, in time for first collisions and the beginning of datataking with colliding beams. The core EPICS infrastructure has proven to be very robust; serving on the order of $10^5$ individual data channels over 15 IOCs in a heavily used network environment. Access to the source code has allowed for the development of BaBar-specific hardware device drivers and minor modifications to the user interface that benefit the shift crew. The communication link between BaBar and PEP-II has also been very reliable, and has contributed to a high overall operating efficiency. BaBar has also benefited significantly from the expertise of the EPICS Collaboration and the wider user community.

Although ultimately successful, implementation of the Component Proxy and ODC integration into the Online system has not been easy. Dependencies between the different components of such a tightly integrated system mean that development delays in one area may cause delays in other areas. In particular, problems with operational efficiency and scalability of the Objectivity database affected almost all aspects of software development during the commissioning phase of the experiment. In addition, the ”locking” mechanism that regulates reading and writing to the database created conflicts between different online processes that negatively impacted datataking efficiency. However, despite these initial problems, the benefits, in terms of adaptability and automation, are already observable.

## Acknowledgements

We wish to thank the following members of the BaBar Detector Control Group for their contributions: M. Bandioli, C. Brown, F. Galeazzi, K. Kang, M. Kocian, P. Fischer, C. Roat, C. Thiebaux, and V. Tisserand. This work was supported by the U.S. Department of Energy contracts DE-AC03-76SF00515(SLAC) and DE-AC03-76SF00098(LBNL).

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