Real Time CORBA For Mission Critical Systems - Space Vehicle Static Testing

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a. Introduction, Scope of Work, Abstract

This presentation on the topic "Real-time CORBA for mission critical systems – viz space vehicle static testing" is based on case-study/research work carried out.

- In a real-time environment, timeliness is an essential factor and it is as important as that of functionality.
- Missing a deadline would result in total failure for mission critical applications.
- In soft real-time systems, violation of time constraint to a certain extent may not lead to critical failure.
- However, deadline could never be missed in hard real-time systems.

- Resource management, predictability of the systems and reliability plays a key role while developing real-time systems.

- In heterogeneous, distributed real-time systems, the middleware plays an important role in determining the predictability of the system.

- In this presentation we discuss the application of OMG's Real Time CORBA in a mission critical system, viz. space vehicle static testing.

- The development of a CORBA based real-time system for monitoring and controlling various critical parameters like engine chamber pressure, thrust, propellant flow, various temperatures, valve status for static rocket engine test is discussed

b. Static Rocket Engine Test

- For a successful rocket launch, two stages of developmental test activities will be carried out. One is the static test of the launch vehicle and other is the flight version.
- Static rocket test is the testing of one or more stages of the launch vehicle in the launch pad, while they are stationary. Static rocket engine test will be carried out at sea level.
- The test parameters of static rocket engine test will be monitored by the respective Scientists/Engineers. Many of the test parameters are critical with respect to time and some are non critical. Critical parameters are monitored and corrective measures will be taken by the test Engineers. Some of the critical channels will be the controlling factor for real-time testing.
- Rockets are being developed by most of the countries and static testing of the launch vehicle is essential to achieve their goal.

- During the developmental stage of the rocket, it has to undergo so many qualification testing of rocket main engine and sub systems.

- Before testing the main engine of the rocket, subsystems of the rocket will be tested in auxiliary test stands. The main engine with the qualified subsystems will be static tested in main engine test stand. Here many parameters are monitored during static test and they undergo several changes before flight testing. Some essential parameters of the static rocket engine test are to be inspected, verified and supplied to the flight testing group. So static rocket test is a critical test for any rocket to be launched.

- Upper stages of space launchers, which could place communication satellites into Geosynchronous Transfer orbit, require stages with higher specific impulse (Thrust developed while firing 1 Kg of the propellant per second for an ideal case).

- Cryogenic stages, which use liquid hydrogen and liquid oxygen as propellants provide very high specific impulse and hence become the obvious choice for upper stages of Geosynchronous launch vehicles.

- The static testing of a space vehicle includes validation of the Rocket engine, turbine and pump assemblies, which form the main elements of cryogenic propulsion.
- This testing requires state of the art and sophisticated instrumentation support for control as well as monitoring purposes.
- A dedicated control and monitoring system is required along with control system hardware.
- It provides facilities for command generation to control system along with real-time system with various measurement parameters, valve ON/OFF status and command for Electro Pneumatic (EP) valves.
- Programmable Logic controllers (PLCs) are used for low level communication and they interact with the control system hardware.
- Huge number of channels have to be controlled by the PLCs that are part of the control system network. Each PLC will be responsible for performing its own local activities and it could communicate with other PLCs of the network in a complex and inflexible control system. These PLCs will be controlled by a master Real-Time CORBA based control system.

- In case of abnormal test results, the control system is responsible for correcting the abnormalities and to abort the rocket engine test if corrective actions could
  not be applied.

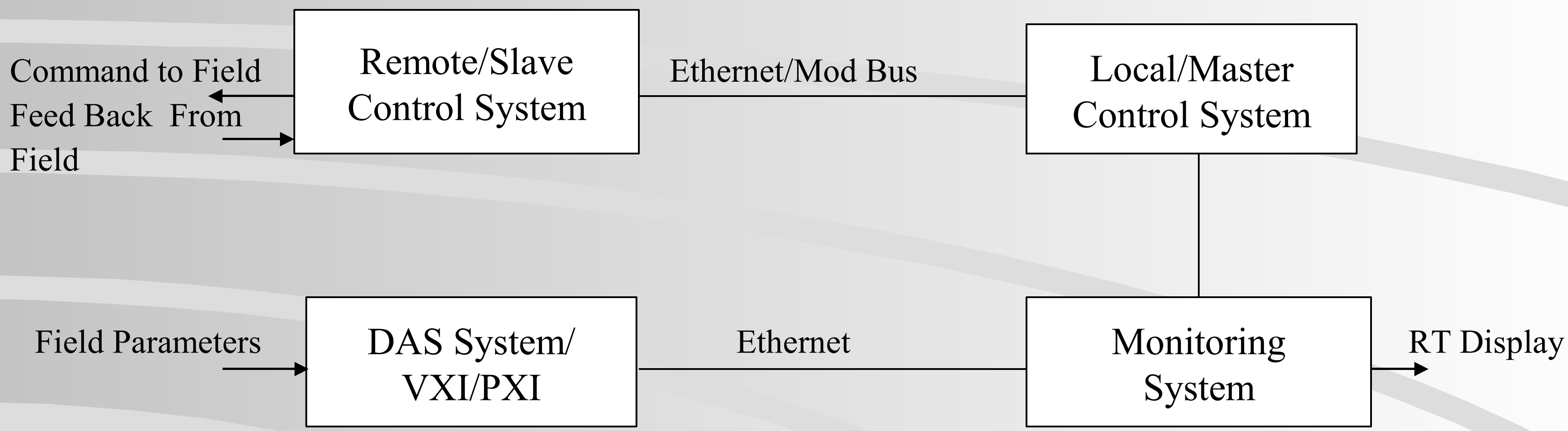
- Monitoring system should log all the real-time data retrieved using Data Acquisition Systems for off-line processing and for on-line display of most critical parameters. Real-Time CORBA based Monitoring system will handle these parameters by associating appropriate priorities for on-line display and off-line data processing.

- The static rocket engine testing is performed during development
  Phase as well as the qualifying phase (pre-launch phase).

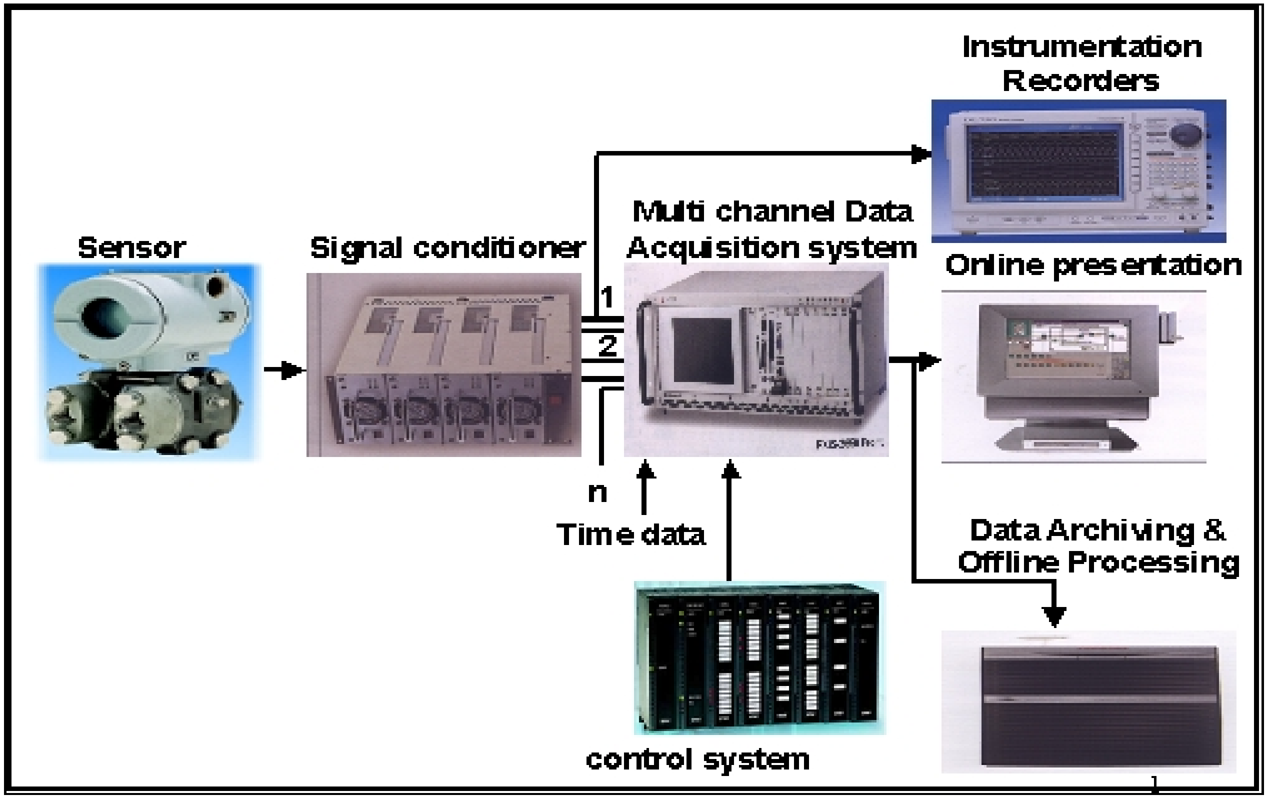
- The developmental phase testing involves dynamic scheduling of Real-Time CORBA since the workloads could be unpredictable.

- In contrast, the workload for the qualifying phase of static rocket engine test would be predictable and hence the static scheduling features of real-time CORBA can be used here.

c. Architecture Overview



Master Control System and Monitoring System are Real-Time CORBA based Systems


Instrumentation
Recorders
Sensor
Signal conditioner
Multi channel Data
Acquisition system
Online presentation
1
2
n
Time data
Data Archiving &
Offline Processing
control system

d. System Description

- PLC based control system is used to control the opening and closing of field valves. Each I/O module of the PLC has numerous channels to control the relays/field valves

- Computer in the Ethernet network can communicate with the controller using Modbus/TCP advanced industrial protocol.

- PLC will have a start button to initiate control system activities. It will send a synchronization signal to the PC server to read various field parameters   obtained through the Data Acquisition System.

- Alternatively, control system activities could be initiated manually if user intervention will be required for the developmental activities.

- Once PC Server receives the synchronization signal from the PLC, it will start reading data from the data buffer in which Data Acquisition System puts the data.

- PC server will send the Real-Time data to display units for On-line display. It will also store the real-time data in database for on-line processing.

- Operator can manually provide commands to the control system using the PC GUI. PC server writes this data in a buffer and those data will serve as input to Control Systems for command generation.

- Backup server (secondary/redundant server) will also be running and it will take control if primary server fails.

d.1 Real-Time CORBA based Server for Command Generation and Data Acquisition

d.1.1 Real-Time CORBA Server interaction with Control System

- CORBA based master controller determines the priority of the signals it receives from the PLCs using server propagated priority model. Priority banded connections will be used for this.

- As timeliness is the most important factor of a real-time control system, for distributed control system discussed above, real-time CORBA middleware co-ordinates various activities done by different PLCs located at different places and makes the system highly predictable.

- PLC will send a synchronization signal to indicate the start of data acquisition process to the Operator based Server.

- As per the ladder logic(pre-programmed logic) of PLC, the valves will be controlled.

- PLC can also send the on/off status of the valve to the CORBA based Server. For cases where high speed data acquisition is required, VXI/PXI based DAS will be used.

- Based on the Valve status, Operator can manually generate commands using the function keys. CORBA Server will send the user command to the PLC which interacts with the hardware.

- PC and PLC could communicate using the modbus protocol. Converter/Bridge will convert the RTP/IIOP messages sent from the CORBA Server into Modbus protocol and route the control system inputs to the PLC.

- In case of unexpected critical failures, Operator could abort the engine test through the Operation station CORBA Server, which takes the highest priority of all or using abort button in the PLC.

d.1.2 Real-Time CORBA Server interaction with Data Acquisition System

- PXI based Data acquisition system writes the real-time data of parameter values like engine temperature, propellant flow, chamber pressure, thrust etc to a file in the Operator Station.
- CORBA Server in the Operator Station will read this data as soon as it obtains the synchronization signal from the PLC.
- It will log the data for off-line processing and also dispatch the measured real-time data to the display units.

- CORBA server based priorities will be associated with the objects for processing the real-time data and threadpools will be set to appropriate priorities for static scheduling.

- Critical parameters that needs to be monitored through on-line display will be provided high priority compared to parameters that have to be logged for off-line processing after completion of static rocket engine test.

- Analog output of Data Acquisition System will be converted to digital using A/D converter.

d.1.3 Back-Up/Redundant Server

- Operator station CORBA server will be running in fault-tolerant mode. Primary server will log the real-time data.

- If primary server fails, then secondary server will perform all its functionalities.

d.1.4 Controller and DAS Sample IDL

Sample IDL description for Control System Input, Manual Command Generation and Data Acquisition System.

```
module Controller
{
  interface CmdGenerator {
     // To Control Valve Status
     Boolean control_valve(in short plc_id, in short valve_no,
                inout short  valve _status);

     void halt(in short plc_id); // To abort the process
      // To alert CORBA based Server with the synchroization signal
      // from PLC
      Boolean synchronize(in short plc_id, in short alert_flag);
    };
```

```
interface DataAcquisition
{
   // To Obtain Real-Time Parameters.   Monitoring system plays active role

   // based on the synchronization signal from PLC

   Boolean get_pressure(in short plc_id, in short channel_id out long value);


   Boolean get_thrust(in short plc_id, in short channel_id, out long value);


   Boolean get_flow(in short plc_id, in short channel_id out long value);

   Boolean get_temperature(in short plc_id, in short channel_id,
                                   out long value);
};
  …
  // User Exceptions
};
```

Controller::CmdGenerator object should be associated with high CORBA priority compared to Controller::DataAcquisition object. Critical section associated with fetching the real-time data will be synchronized using RTCORBA synchronization mechanisms.

d.1.5 Advantages

- Deterministic
- Reliable
- Predictable
- Extensible
- Cost-Effective

d.2 Real Time Monitoring and Animation Display

- Measurement Parameters will be sent to animated display units for monitoring in the control room.
- Test result parameters could be Published to N number of display units using real-time Event Service[QOS configured as per the real-time requirements].
- DAS will write the data to live.dat file, which is a sharable file. CORBA Server reads this data and store it for off-line processing.
- Real-Time display module reads this data and send it to display Units.
- Sharable file mode read operation is required because the CORBA Protocol converter updates the same live.dat file once in every 0.5 sec.
- Hence simultaneous access is allowed only in sharable mode.

- The data received is equivalent to binary value of voltage or Current given to analog input card in the control system.
- In case of digital input card two bit data will be taken from micro switch of EP valve.
- One bit data will be taken from ON/OFF status of pump.
- Bit status one represents “Pump ON” and zero bit status represents “Pump OFF” condition.
- The analog binary value received from analog input card is converted into engineering value using sensor calibration data. The sensors are calibrated in the calibration lab and corresponding voltage vs engineering values are obtained before test.
- This calibration constant will be kept in analog master file in the server.
- The program reads the constants and converts all binary voltage values into engineering units.

d.2.1 Monitoring System Configuration

- Test stand process is displayed in the operator station by animated fluid circuits.

- The EP valve ON/OFF status and process parameters are displayed by superimposing the display over the animated fluid circuits.

- Also the measurement parameters will be sent to various display units even at remote places for monitoring the on-line data and logged for off-line processing.

d.2.2 Work Flow

- CORBA Event Supplier will read the data from live.dat once in every .5 sec and pushes the data to the Real-Time Event channel.

- The Channel will push the data to various distributed event consumers. Event consumers will publish the data to respective heterogeneous display unit connected to it like large scale display, Remote digital meter display,animated fluid circuits etc.

d.2.3 Advantages

- Decoupled information transfer between the consumers and supplier.
- Configurable appropriate QOS. Simultaneous dispatch to all the display units is taken care by the Event Server itself.
- Event filtering could be achieved by registering consumers to specific event channels alone.
- This is required to view critical parameters alone instead of looking into all the data.

e Additional/Future Work

- Static scheduling of Real-Time CORBA discussed above will be sufficient for the qualifying phase of static rocket engine test. Research should be carried out for using dynamic scheduling of Real-Time CORBA for initial developmental phase of static rocket engine test as the workload would be unpredictable.

- Research could be extended for using the Real-Time CORBA control and monitoring system of static rocket engine test for space vehicle during flight.

f. Acknowledgments

Thanks to Mr. J.M Baskaran, Dr RamaKalyan, Mr. S.G Thangadurai, Mr Gopi

Kumar Bulusu and Mr Murali Desikan for their valuable comments!

Thank You one and All!

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