Project Firepower, US Navy

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1.0 Introduction

Project Firepower was a project of the United States Navy's NavAIR (Naval Air Warfare Center Weapons Division) in China Lake. The objective of the project was the study of fire propagation and suppression in aircraft cockpit and fuselage by means of physical experimentation, computational simulation and theory. Naturally, the three are a coupled triangle with Simulation Science serving as both an expansion of Theoretical Science and as a contraction of Experimental Science-- coupled into a feedback loop of refinement. However, this project received a unique coalescence of the Theoretical and the Experimental and the Simulacrum courtesy of the design of Lakhvinder™.

In 1995, after only two days, Lakhvinder was asked to design a system for the project.

2.0 Mission

2.1 The Apparatus

The apparatus for the project consisted of a testbed foundation capable of tolerating the tremendous thermal and reactant load. Embedded within this foundation were sensors and a fiber optic interconnect fabric. The foundation also included various subsystems such as water / suppressant supply tanks and feeds, reactant feeds, igniter feeds, and power feeds. Atop this foundation sits a section of fuselage rigged with sensors, ignition sources, reactant delivery, suppressant distribution and other subsystems all plugged into the fiber optic fabric embedded into the foundation.

With this "Dante Laboratory", a fuselage or cockpit fire could be initiated with an unprecedented level of control over the starting conditions for the experiment. Furthermore, the nature of the fire could be controlled throughout the duration of the experiment within the limits of subsystem survivability and event controllability. The fire could be manipulated at the beginning of each experiment and during the course of the experiment through creative manipulation of the ignition systems, reactant systems, ventilation systems and the water / suppressant systems. Thus, this fire propagation experimental laboratory allowed for desired starting conditions for the nature of the inferno under study. During the course of the experiment, the fire could be manipulated and adjusted in progress. Fire suppression studies allowed for initiation of the fire with desired starting conditions, and then, began the application of the fire suppression technique and systems for the fire suppression / propagation under study-- then the apparatus allowed for manipulation and adjustment of the fire suppression and the fire propagation itself during the course of the experiment. All with a tremendous amount of information being gathered through the various sensors.

At this point compliments must be paid to two of our friends at China Lake. These two impressive men are two special characters. This laboratory / apparatus was of their design and intestinal fortitude.

2.2 The Constraints

After only two days, Lakhvinder was asked to design the computational system for the apparatus which would bring together the three pieces of the apparatus and the three pieces of the coupled triangle. Lakhvinder's design, however, coalesced the Theoretical, the Experimental and the Simulacrum to a much higher degree.

Due to the nature of the project, Lakhvinder was given data in a piecemeal fashion with tremendous technical constraints including:

- highly demanding constraints and tolerance ranges on the fiber optic interconnect fabric and related couplers.
- precise datum quantities and datum frequencies which had to be met in real-time.
- general descriptives on the datum which required Lakhvinder to design compensation for

variation of the nature of the datum over a broad range whilst still insuring real-time handling within a tight range of tolerances.

- general descriptives of drop-in algorithms whilst still insuring real-time handling and integrability with general descriptives of tight tolerances of loop instruction counts and loop iterations.
- drop-in integration with a modular interface for undisclosed, off the shelf, and modified or encapsulated off the shelf sensors and control system devices.
- rugged MIL-SPEC and NEMA constraints for in the field environment and power.
- real-time, reliability and fault tolerance as conducive with the personnel and materiel danger and risk associated with the nature of the experiments and apparatus.
- many other demanding constraints and tight tolerances all defined within the limitations on information flow and communication as a result of the nature of the project.
- the system serves the roles of data acquisition with real time processing, control systems for the apparatus, and as the console for the entire apparatus.

3.0 The Solution

Lakhvinder designed a system which surpassed all constraints and allowed capabilities beyond all reasonable and unreasonable expectation.

Lakhvinder designed a multi-role system which not only served the roles of operating the entire apparatus as data acquisition, control systems operation, apparatus console and experiment command-center-- the system, when not in use for an experiment on the apparatus, could be used as a Supercomputer by the Theoretical and Simulation personnel. Lakhvinder designed a system which coalesced the entire triangle:

- for the experimental side: fault tolerant data acquisition and control with real-time preprocessing of observed quantities to calculate and predict derived quantities for enhanced real-time experiment decision making and control.
- a Supercomputer for the Theoretical and Simulation side.

The Lakhvinder system was comprised of off the shelf components with Lakhvinder custom modification, addition and integration. Off the shelf components were selected from families of products to insure longevity and availability as well as generational viability.

3.1 The Array

The Lakhvinder system was based on an array of off the shelf modified hardware, all MIL-SPEC NEMA rugged, from boards to processors, semiconductors, enclosures, cables, couplers, memory, mass-storage, to keyboards, pointing devices, dial boxes, button boxes, klaxon's, lights, shock mounts, monitors and cooling systems. The operating system was an of the shelf UNIX-based real-time operating system, coupled together by Lakhvinder into a cellular structure for single array system image and fault-tolerance. When running the apparatus, the system formed into sub-arrays.

3.1.1 Sub Array 1: Telemetry and Control Streamer

The first sub-array was comprised of 4 banks, 2 banks of redundant I/O planes and 2 banks of redundant processor/memory elements. The 2 I/O banks contained data acquisition boards with fiber optic connectors connected to the sensors and (digital to analog) and (digital to digital) boards interfaced to various control system devices from valves to pumps, motors and any other analog or digital device. The 2 I/O banks provided double redundancy to the apparatus devices including separate redundant fiber optic paths to the foundation and embedded within the foundation. The 2 banks of processor/ memory elements were cross configured such that either processor bank could service either I/O bank. Double redundancy throughout. This sub-array received all telemetry from sensors and polled the sensors for diagnostics, whilst streaming the data to another sub-array and reporting the state and state change of the sensors. This sub-array also controlled all control system devices, this sub-array did not process the controls system logic-- rather, it sent commands to the devices based upon the state desired by another sub-array. This sub-array also polled the control system devices for state, change of state, verify state and diagnostics. This sub-array operated and monitored sensors and control system devices. The system also performed continuous diagnostics and dealt with anomalous, malfunctioning and destroyed sensors and devices. This sub-array also ran the device drivers for the boards, sensors and devices.

3.1.2 Sub Array 2: Telemetry Preprocessor

The second sub-array, the preprocessing sub-array, consisted of processor/memory elements. This sub-array processed telemetry in real-time-- detecting and filtering anomalous data, ordering observed data and executing algorithms to calculate quantities derived from the observed data-- all in real-time. This derived data provided calculated quantities which are crucial in decision making for the experimenters in monitoring and running the experiments. This sub-array was, of course, implemented in double redundancy.

3.1.3 Sub Array 3: Data Bank

The third sub-array, the storage sub-array, consisted of redundant banks of processor/memory elements and I/O banks with mass storage controllers. This sub-array stored all telemetry, all states, logs, selected derived quantities and selected predictive data in real-time to disk-array and a delayed dump to tape. This sub-array also retrieved data for the control console as needed.

3.1.4 Sub Array 4: Master Control

The fourth sub-array, the master control sub-array, consisted of processor/memory elements and I/O banks containing video controllers, graphics processors, breakout box controllers, and controllers for keyboards, pointing devices, monitors, displays, dial boxes, sound and button boxes. This sub-array processed the logic for automated control of the apparatus as well as providing the control console for the experimenters to conduct and observe the experiment. This sub-array graphically presented the data, the derived data, the predictive data, the state of devices and the graphical control interface for the apparatus. Everything from temperature, delta temps, flow rates, valve position, consumables tank volumes to gas sensors and imagery.

3.1.5 Sub Array 5: Predictive Simulator

The fifth sub-array, the predictive sub-array, consisted of processor/memory elements. This sub-array ran real-time simulations feeding predictive data to the the experimenters to serve 2 purposes:

- to compare a running theoretical model constantly adjusted and fed with real-time data, to the actual experimental data in real-time. This allowed experimenters to make decisions to manipulate and adjust the experiment to gain maximum insight and understanding from each experiment. This would allow experimenters to adjust for testing theoretical limits or for investigating experimental variations.
- second, predictive data in real-time gives experimenters a theoretical glimpse forward predicting the direction of the experiment thus providing experimenters with a theoretical lead-time for decision making and providing possible hazard avoidance. Experimental data fed through a theoretical model, in real-time.

Real-time Situational Awareness.

3.2 Gestalt System View

3.2.1 Systemic Longevity and Evolution

The systems modular array-based architecture allowed for scalability in all elements from processor/ memory to I/O, boards, devices, human machine interface, disk arrays and tape. Even the I/O banks could be swapped for new backplane buses.

The Lakhvinder systems software is of a completely modular design built within the framework of a high level graphical programming environment. A strict framework provides for template simplicity for China Lake personnel to add undisclosed devices, preprocessing algorithms, predictive simulation algorithms, additional items of visualization and graphical control interface-- whilst encapsulating these within the strict real-time extensions and fault-tolerance of the system, thus insuring that extension of the system never compromises the integrity of the system. This also served to address some of the constraints imposed by the nature of the project such as undisclosed sensors and devices, the ongoing development of simulation algorithms, and the integration of new sensors and devices through a generalized device interface. The graphical programming environment and the framework afforded modular construction of algorithms, device support code and control interface additions in a manner which then allowed for module isolated compile followed by graphical integration of the new module into the system.

The culmination of the Lakhvinder approach in this hardware and software allowed for simple modular integration of new hardware sensors, devices, buses and I/O boards into the software and OS. Conversely, it also allowed for the simple translation of the software across generations of the hardware. Modular, robust, scalable hardware and software-- simple integration of hardware, simple integration of software. Concentrate on the job, on the work, not on the tools.

3.2.2 Mysterious, rugged and mobile

China Lake had noted the "environment" for the foundation and, additionally, had noted the possibility of other foundations at "other locations". Details were scarce, as the nature of the project dictated. Lakhvinder compensated for the variables by designing the system as completely rugged and mobile. Lakhvinder designed the system with the form factor of a standard shipping cargo container. This includes the entire array, control consoles and cooling. Lakhvinder selected this form factor as a constraint for it's universal applicability. This form factor can be loaded onto the standard flatbed trailer of standard military and civilian trucks. This form factor is also amenable to temporary placement in standard test range environments. This form factor can be fitted to standard military vehicles used as a base chassis for supply, missile launch, rocket artillery and other chassis. This form factor can be placed easily adjacent to, or within, buildings. This form factor is also compatible with the C-130 Hercules aircraft. Lakhvinder chose compatibility with the C-130 Hercules rather than it's larger counterparts as a result of it's ability to operate STOL and the turboprop capabilities to operate in the widest range of environments with or without runway facilities. It seemed most conducive with the system. Naturally, the form factor itself lends to Naval Oceanic compatibility.

While China Lake specified power availability on locations, Lakhvinder designed a contingency of a similar form factor additional container to house a generator. Still one truck (double flatbed trailers), one Herc. Integration with a standard military chassis would allow the entire system in one vehicle with power from the vehicle engine mated generator, and drive on compatibility with the Herc.

3.2.3 Experimentalist and Theoretician

In addition to all of these capabilities, when the system is not being used for experimentation with the apparatus-- the system has available all processor/memory, graphics, human interface and storage elements as a supercomputer for experimental sciences data analysis, in the field. Additionally, the system is then available as a fully functional supercomputer for theoretical and simulation sciences.

A practical, logical, multi-role, mobile, shared, rugged data acquisition/control system and supercomputer in the field for Experimental and Theoretical and Simulation Sciences.