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Paper Session II-B - Automated Launch Vehicle Command & Control Center

Roger F. Block
Manager of Advanced Programs

Hoyt M. Layson
Sr. Project Staff Engineer

David V. Wilson
Senior Engineering Fellow

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AUTOMATED LAUNCH VEHICLE COMMAND AND CONTROL CENTER

Dr. Roger F. Block
Manager of Advanced
Programs

Hoyt M. Layson
Sr. Project Staff Engineer

David V. Wilson
Senior Engineering
Fellow

Honeywell Space and Strategic Systems Operations
13350 U.S. Highway 19 North
Clearwater, FL 34624-7290

ABSTRACT

The current U.S. earth-to-orbit expendable launch vehicles (ELVs) and space transportation systems (STS) require labor intensive, expensive launch site preparations, on-pad vehicle checkout, and launch support. By using state of the art, commercially available technology, these operations can be automated to reduce costs and improve mission success. In addition, the technology allows remote launch monitoring and personnel reductions at the launch site. Today's industrial work stations, computers, communications hardware, and data bus equipment, in use throughout the process control industry, can be integrated with existing avionics and organized into a modern avionics architecture. Such an architecture could replace the current launch site, push button implemented, command and control and the plethora of strip chart performance monitoring systems. The new avionics architecture defined by Honeywell features a user friendly electronic data base/archiving system coupled to a real-time command/control capability. It is designed to automate much of the launch operations, significantly reducing the current "standing army" and high associated costs of supporting today's launch systems.

Honeywell industrial automation and control hardware and software products have been configured into a flexible system architecture allowing the transition from an archaic manual approach to phased levels of increased automated test and checkout in launch operation systems. The new approach supports open systems interconnect, scalable fault tolerance and modular build up of automated capability, while

making extensive use of industrial and commercial standards. This application fully exploits the investment and extensive controls experience achieved by the nation's industrial automation and control industry during the last 30 years.

Current Launch System Status

Current launch systems, comprised of diverse and aging components and subsystems, are costly to operate due to lack of automation. There is a need to bring the entire life cycle process for launch vehicles, from component design to vehicle launch, to the state of the art in industrial automation and control equipment. The infrastructure of today's launch systems includes equipment so old that, in some cases, spares are not available. It is so customized that performance upgrades are costly. It is not amenable to supporting and integrating an electronic data base of the life cycle aspects of launch vehicle assemblies and subsystems. The current launch systems could benefit from open system information management architectures that support distributed information exchange and evolutionary systems growth. They could use more modularity, flexibility, and automation. They would greatly benefit from more extensive health monitoring, diagnosis and test. The commercial industry has for a long time realized all of these benefits. They have developed and implemented modern industrial automation and control products to automate complex and safety critical processes.

The Vision for Future Launch Systems

The USAF/NASA National Launch System (NLS) program is driving to reduce future launch costs by as much as an order of magnitude. This

will require a whole new way of doing business. The new family of launch vehicles will include modern avionics with higher levels of fault tolerance and feature extensive use of vehicle health management technology. However, the significantly lower launch cost goals can only be achieved by performing most of the assembly, integration, and checkout of the vehicle and payloads at the launch site. Further, these critical operations must be highly automated to significantly reduce the number of launch support personnel. This modern approach to future launch operations and processing is illustrated in the NASA plan shown in Figure 1.

Honeywell has been working with the USAF National Launch Systems Joint Project Office (NLS JPO) and launch primes over the last three years to define a cost effective approach to achieve this visionary goal. Our approach is to leverage the 30 year experience and technical investment made by the industrial automation and controls community.

Current Industrial Process Control

Automation and control has been applied to many industrial processes to reduce costs, improve safety, increase quality, predict failures, and reduce scrap. The processes are varied and diverse ranging from a single continuous process like a bottling line to the integration of hundreds of separate discrete processes as in an automobile plant. Critical processes in oil refineries or chemical plants and quality processes such as pharmaceutical plants have now replaced highly trained personnel with industrial automation and controls. Industrial automation and control utilizes health monitoring of motors, pumps and furnaces to predict failures and plan maintenance to avoid catastrophic system outages.

Honeywell has led the industry in addressing the spectrum of modern automation and control from distributed sensor and actuator technology to generating the full complement of data needed by management. Figure 2 depicts the hierarchy of today's industrial automation and control architecture.

Industrial automation and control has evolved over the past 30 years, immediately incorporating new technologies as they become available. Most industrial processes which were previ-

ously manually intensive have been successfully automated. Industrial automation and control hardware products, from sensors to mainframes, have been distilled into hierarchical building blocks. Using open system architectures, these building blocks are integrated to realize the overall automation and control system for the process. The use of open system architectures (1) permits the addition of new technology products for the future, (2) allows for integration of diverse components from different suppliers (interoperability) and (3) eases the flow of information among diverse systems.

Through this evolutionary period, industrial automation and control software development tools have been continually refined. Today's tools permit plant-floor personnel who are knowledgeable about the process (but untrained in software) to be able to automate, monitor, and receive reports on the process. The software tools that are required to automate a process with today's industrial automation equipment have been formatted to be extremely "user friendly". They are object oriented using symbology and icons that are familiar to process personnel just as object oriented programming languages using icons and menus have an interface that is familiar to office and management personnel.

In addition to automating the process, industrial automation and control products encompass the management aspects of a manufacturing or processing plant. From incoming receiving of raw materials and components to the shipping of the finished product, industrial automation monitors and controls the process and, equally important, generates the enterprise and administrative reports for the board of directors.

Application of Industrial Automation and Control to Launch Systems

There are many parallels between launch systems operations flow and industrial processes. However, industrial processes are fully automated, in contrast to today's launch processes. There is no reason that many launch processes and operations cannot be similarly automated.

In general, launch system operations flow can be partitioned into standard industrial processes. Each of these processes have implications in the process equipment used. This includes control bandwidth, type of interface

data (sensors to status reports), level of control (supervisory to fully automated) and type of equipment (sensors, processors, actuators and terminals). The existing launch processes, such as vehicle assembly and checkout, payload encapsulation and launch control, can be readily integrated into an automated launch system using this equipment. Just as important, however, is providing the information necessary to manage the overall integrated system. We believe that the largest benefit of automated launch control operations will accrue by providing launch management and support personnel with real time visibility of the preparation processes.

One aspect of how industrial automation and control could be applied to the launch system is the life cycle process of the equipment. This is illustrated in the following steps:

- At the design phase, each subcontractor is provided the equipment needed to establish a data base on his hardware and software that will be delivered with each subsystem. In addition, launch personnel would do the same for items designed and developed at the launch site.
- As the phases evolve (development, test, evaluation, integration and verification), information is stored for use at the subcontractors plant and at the launch site.
- As the vehicles come together, launch operations are added to the overall plant and factory information system such that launch operations can obtain data on the launch vehicle all the way back to the design phase.
- While the launch vehicle is on the pad, continuous test results are compared to previous tests performed on the vehicle and payload and even to previous launches.
- Post mission analysis results are used to provide a continuing update to the launch factory data bases for statistical quality control and statistical process control to assure continuing quality improvement.
- Ultimately, financial data on the launch systems is compiled from the distributed

data that exists throughout the launch system factory, from the receiving dock to on-orbit. Engineering data on failures, repairs, and refurbishment are combined with financial and safety data at the factory and enterprise level to aid in management decisions.

The NLS program is addressing modernizing the entire launch "system infrastructure" shown in Figure 3. This networks an external, national team of government agencies (USAF SPOs, NASA Centers), aerospace prime contractors, and scores of subcontractors and vendors into an integrated data and information management system. The launch site complex, launch vehicle, and payload processing are also coordinated and managed as an integrated system. This can be viewed as an industrial process with the NLS level as the "enterprise" level (refer to Figure 2). Visibility into the process may go as low as necessary to track status, initiate sub-processes and perform detailed analyses. This includes analyzing vendor test data for trends, tracking LRU serial numbers and drawings, monitoring fuel flow valves and sensors at the launch site, and monitoring the progress of tests on the launch vehicle. Via a nationwide communication network (UNIS), even engineers at the vendor plants can monitor the progress of testing on their equipment and take an interactive part in reviewing data and addressing anomalous behavior. This alone could have a significant impact in reducing the "standing army" at the launch site.

The following discussion focuses on a significant element of this infrastructure; the launch control center. It describes how standard industrial automation and control equipment can be applied to the launch control center.

An Approach to Automated Launch Control

The system architecture shown in Figure 4 illustrates an approach for automating the launch control operations. It consists of equipment located at a local block house adjacent to the launch pad and in a remote launch control center. At the block house, standard programmable logic controllers (PLC) with associated input/output module racks will gather "user" defined analog/discrete vehicle data and provide capability for local command and control. Block

house resident data monitoring and test equipment will consist of several terminals residing on a local block house Local Area Network (LAN). The vehicle data will be provided to the rest of the system via a fiber optic communication link.

The launch control center (LCC) will contain the major data acquisition, information archiving, subsystem performance monitoring, and "user" remote command and control capability. All real-time launch operations data entering the LCC on the fiber optic link will flow to multiple data acquisition system (DAS) units where a "user" defined data subset will be transmitted to and archived on the terminals. The DAS units will function as the real-time data base for the LCC operations. A complement of standard Manufacturing Automation Supervisor (MAS) processors will be used to gather real-time launch operations data and selected historic data and provide graphics, and data formats and displays to all the terminals in the LCC and the other terminals at the blockhouse locations. In the LCC the terminals will be configured to simultaneously support both data monitoring and remote command and control capability. Of course, all terminals throughout the distributed LCC system will be capable of data monitoring.

The system just described and presented in Figure 4 represents a capability to meet the presently envisioned fully automated launch system checkout and health monitoring requirements anticipated in future launch operations. Because of its modular, flexible, open systems architecture, simple subsets of this complete capability can be configured initially, depending on funding and specific needs for data acquisition and command and control authority.

The terminals, MAS processors, DAS units and data storage equipment are based on off-the-shelf products proven in decades of operation in industrial automation and control environments and in selected launch environments. The multifunction touch screen and state of the art display systems on the X-window terminals eliminate the need for push button consoles/panels and "banks" of stripcharts recorders. The terminals provide real-time performance monitoring. The system will provide all the "hooks" and "scars" to fully automate the launch process. This is important to support transition to full automation and electronic storage. Conventional equip-

ment, such as strip chart recorders, can be easily integrated into the system and phased out as confidence in full automation builds.

The standard MAS processors provides all the system software tools required to define the data and display formats for command and control, as well as performance trending. It also provides the software tools and libraries required for rapid prototyping of the launch process control. This allows the launch personnel to simulate the appropriate level of automation for each subprocess and validate the process prior to going on line.

Fault Tolerance

The system architecture provides a sufficient level of redundancy at critical points in the system.

- The programmable logic controller in the blockhouse is configured as a dual redundant system using a hot spare to support the vehicle safing function. In the event of a primary and backup communications link failure, the blockhouse equipment will automatically sequence the vehicle to a predetermined, safe condition.
- Virtually all the terminals provide duplicate capability for data display and command and control.
- As the system design evolves, added fault tolerance and redundancy can be easily added and tailored to the defined need. This is a result of the modular features of the current industrial automation and control equipment.

Benefits of COTS

Future automated launch operations will achieve significant benefits in both development costs and full life cycle costs through the maximum application of commercial off the shelf (COTS) products.

- The products represent state-of-the-art technology proven in a world-wide customer complex for over 30 years. The equipment has performed to the exacting standards of industrial process control in

applications that are similar in criticality and safety to launch vehicle operations.

- The COTS hardware and software is generally upgraded in technology and capability every 3-5 years to stay competitive in the industrial controls world. Thus, the equipment is always riding the "technology bow wave" and is never obsolete.
- As upgrades in automation and control capability are implemented, the existing equipment is upwardly compatible — the up front investment is never compromised.
- The products are modular, scalable to satisfy virtually any controls architecture required by the launch system. Thus, the initial launch operations system can be simple to meet initial needs and then it can be evolved cost effectively to achieve a full automation capability. It can be tailored to the level of automation sophistication required to fit the needs and budget.
- Since COTS products manage critical processes on a daily basis, scalable levels of fault tolerance can be added at critical system or process points. Hot or cold spares at critical points is normal for the process/power industry.
- The COTS products are designed for open system architectures and implement in-

dustry standards. Thus interoperability with all or most commercial/industrial products is achieved.

- COTS automation and control products are also extremely cost effective because of the large annual production base and competitive markets. Thus, launch systems can exploit the large economies of scale in the industrial controls business.
- The software development associated with automated launch systems is also straightforward and cost effective, since each COTS system includes a wealth of development software tools and libraries that are easy to use in developing controls application software.
- And finally, hardware sparing is generally not required since most elements are standard catalog items that are available as stock from domestic or world-wide distribution centers on a few days notice.

In conclusion, the launch process world must take a closer look at the industrial automation world. In these times of budget constraints, tight schedules and low risk taking, it is essential to capitalize on technology already completed and demonstrated and bring our launch processes into a comparable level of state of the art.

Current NLS Baseline - 2004

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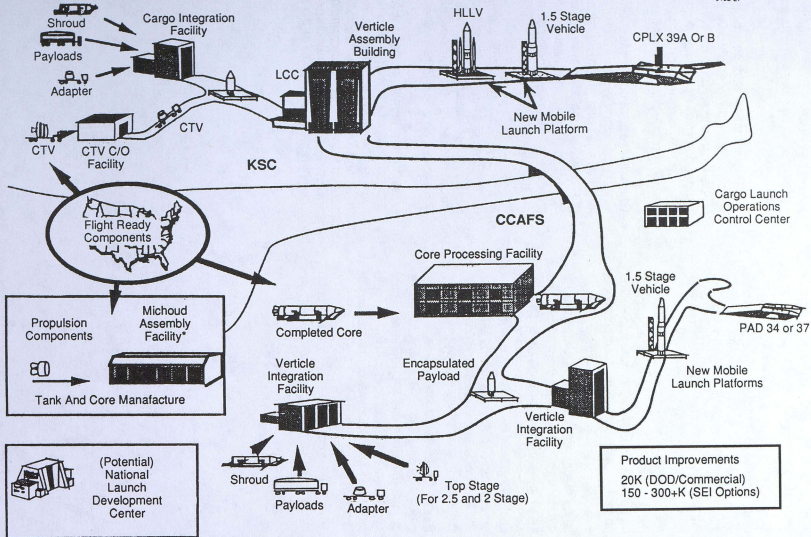


Figure 1. NLS Ground Operations Flow - A Future Vision

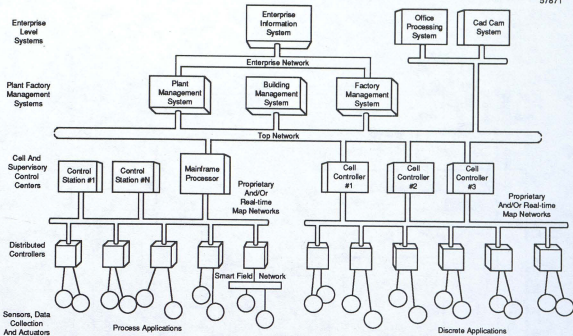


Figure 2. Typical Industry Automation and Control Process Hierarchy

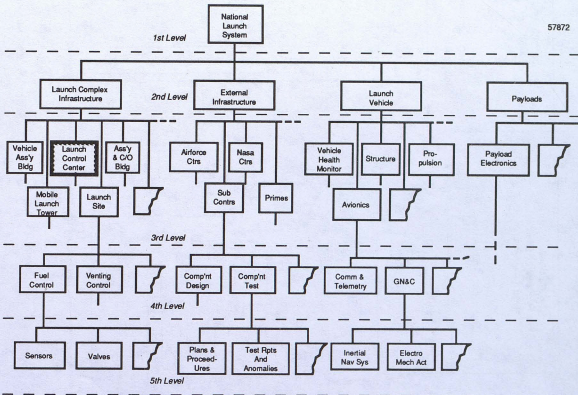


Figure 3. Elements of the NLS Infrastructure

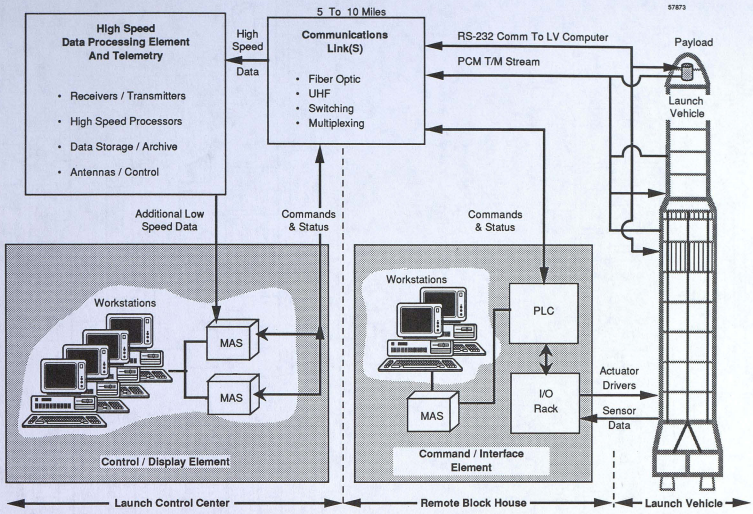


Figure 4. An Approach to an Automated Launch Control