

# Launch Vehicle Engineering Support Products and Services White Paper

## Command and Control Technologies Corporation History

Command and Control Technologies Corporation (CCT) was founded in 1997 as a spaceport technology company specializing in launch control and range safety automation. CCT has built a reputation as an organization that can deliver highly automated systems that advance the state of the art in launch technology. CCT was originally founded to assist companies entering the fledgling commercial space marketplace. These companies required systems that did not inherit the costly and complicated approaches taken by the government ranges and large launch vehicle developers. CCT built a product line and engineering staff committed to challenging the status quo in the launch industry by providing an optimized combination of custom and off the shelf solutions for mission IT applications.

CCT has also found support for this approach within the government aerospace industry and has provided solutions to government launch ranges, NASA installations, and commercial spaceports.

### Our Corporate Philosophy – Not Business as Usual

CCT's founding members sought to create a company that would help launch vehicle designers with new visions and operations concepts achieve their goals of fully commercial launch operations by providing cost effective and highly adaptive ground operations automation.

CCT built a line of products and a team of engineers that shared these goals. As a result, CCT is now positioned to help commercial launch vehicle designers and operators dramatically reduce upfront cost of ground systems software using tools and processes that enable efficient operations. This can be accomplished without the need to adopt existing complex approaches employed by existing launch ranges while still maintaining the highest degree of safety and reliability.

CCT has proven it is possible to:

- Reduce the number of people required to safely process and fly a launch system.
- Adopt a commercial off the shelf and network centric approach to launch and range automation without sacrificing safety or performance.
- Reduce the initial acquisition cost and recurring costs associated with launch processing automation.
- Satisfy the requirements of existing launch ranges without adopting outdated approaches and expensive implementations.

This white paper will outline the ways in which CCT can help space launch service providers (LSP) achieve their operational goals with cost effective, safe, flexible, and reliable approaches to their ground system requirements.

### Areas of Expertise

CCT can provide engineering expertise, turnkey systems, or staff augmentation. The CCT engineering staff is committed to serving the needs of our customers. We listen to our customers and respect the expertise they bring to a project. We work with our customers to thoroughly understand their technical objectives as well as their business goals.

CCT's staff of software engineers, aerospace engineers, and electrical engineers can assist in in all aspects of

- systems engineering
- launch control
- GSE control and monitoring
- range and tracking systems
- telemetry acquisition and processing
- simulation and training
- operational control and collaboration
- launch vehicle factory operations
- payload operations

Each of these areas is discussed in the following sections.

### Systems Engineering

CCT's experienced systems engineers understand business, development, and operational processes associated with the entire launch systems enterprise, and can work with LSP staff to create ground system automation solutions from a very broad set of business or technical objectives.

We can provide the LSP team with system engineering support across the entire ground systems infrastructure or in specific targeted areas such as:

- **Concept of operations and requirements development** for an integrated approach to manufacturing, vehicle integration & checkout, mission planning, launch operations, range operations, payload operations, and operations crew training.
- **Analysis and trade studies** for systems and operational costs, risks, concept alternatives, performance budgets, human factors, and technology forecasting.

- **Architecture development** including system modeling, functional allocation, interface definition, and COTS analysis. Ultimately, the objective is to provide a framework for making technology and product choices (build verses buy) that ensures compliance with business and technical constraints and quality of service across the enterprise.
- **Integration and control** of processes and systems/subsystems/components
- **Verification** of functional, design, and physical requirements; as well as regulatory and licensing requirements.
- **Mission Operations** including refinement of operability based on lessons learned in the field as well as adaptation of systems to new mission requirements. Also includes optimization of total cost of ownership.

### Launch Control Systems

The design and development of robust launch control and launch vehicle processing systems is an integral part of our business heritage. CCT engineers have experience in launch processing systems for the Delta and Atlas launch vehicle as well as the space shuttle. As a result, CCT has been able to apply the benefits, and mistakes, made by these systems to a new generation of control systems that enable leaner operations without sacrificing safety or reliability.

CCT staff were involved in the development of the Delta Clipper flight control system. This system was a fully transportable Flight Operations Control Center designed to allow just a 3 person launch crew to process and fly the Delta Clipper vehicle. This system was the inspiration for CCT's approach to flight operations and forms the basis of the concepts embodied in our product line and development approach.



**Figure 1 Delta Clipper Flight Operations Control Center was a model for lean and efficient operations. CCT team members were leaders in the design and development of the launch control center pictured here.**

CCT launch control systems build on commercial off the shelf technologies to provide an architecture that runs just as comfortably on a laptop computer or in a distributed network computing environment. CCT has eliminated the need to build custom software from scratch for each new

launch vehicle or mission. The approach greatly reduces the up front and recurring costs of operation.

CCT's most recent delivery in this area, the Complex 20 Launch Control System, is included as a case study at the end of this white paper. This illustrates an example approach we have taken and its impact on cost and performance.

CCT can provide a turnkey launch control approach that incorporates all launch sequencing, GSE control, mission planning and post mission analysis functions in a scalable configuration that meets range safety and reliability requirements.

### GSE Control Systems

Controlling Ground Support Equipment (GSE) such as ground power, fuel and oxidizer farms, pressurization and purge gases is an integral part of the launch sequencing process. These procedures often represent the most hazardous operations associated with processing a vehicle for launch. Minimizing human interaction and proximity through the use of remote control, tightly coupled with launch control automation, provides a safer and more reliable approach to the entire launch-processing picture.

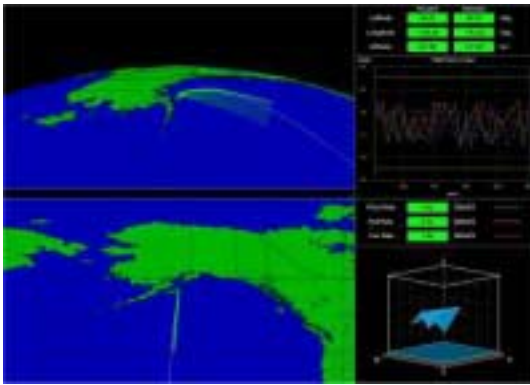
CCT's philosophy to GSE control is very much the same as launch control, avoiding costly homegrown systems to reduce cost and increase performance and reliability. CCT leverages commonly available and well-proven commercial industrial control standards such as the Fieldbus protocol into our product line.

CCT can deliver turnkey solutions for all GSE control and monitoring applications required by the LSP, including fire control, fuel handling, gas handling, power, instrumentation, and data handling.

CCT's most recent delivery in this area, the Virginia Spaceport Liquid Fueling Facility control system, illustrates an example approach we have taken in critical GSE control applications. Contact CCT if you would like a white paper on this system.

### Range Safety Systems

CCT has broad experience in the range safety domain, ranging from launch vehicle safety-of-flight analysis to the design and deployment of range safety data acquisition and decision support systems for ground and flight safety control.



**Figure 2 CCT's range safety and telemetry acquisition experience allows us to provide turnkey systems that meet range requirements.**

While range safety is often a function of the range on which the launch vehicle is operating, having a thorough understanding of how range safety tracking and decision making is performed is a benefit to any launch vehicle program. Our experience integrating launch and range operations has enabled leaner, more efficient operations than have ever been achieved before.

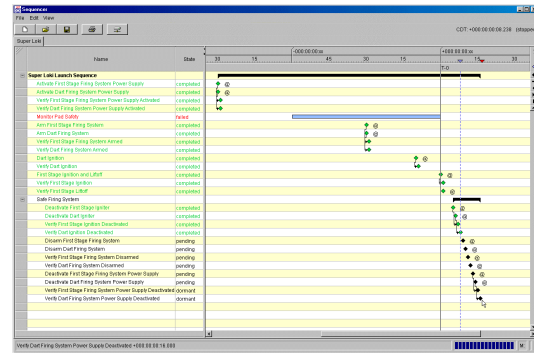
CCT has installed systems at the Kodiak Launch Complex and Complex 20 at Cape Canaveral Air Force Station that provide ground safety, time management, ignition, and hold fire capabilities. These systems include features for mission planning, launch automation, and post mission analysis.

CCT can assist the LSP in working with existing range safety systems and requirements on the operational ranges. Should LSP decide to use a mobile launch range, CCT can deliver turnkey range safety tracking systems that meet all necessary regulatory requirements.

### **Operational Control and Collaboration**

Execution of launch operations has historically been a complex group activity that is managed via a series of hierarchical, and at times quite complex, processes. Traditionally the processes are coordinated verbally, usually guided by tedious procedures, with human operators manually monitoring conditions, recording results, and reacting to state changes.

It has been CCT's experience that effective management of the launch process is a key element of efficient operations. CCT developed T-Zero™ to address operational control and collaboration for launch operations, such that complex operations can be automated for consistent and accurate execution to increase efficiency and improve reliability.



**Figure 3 T-Zero user interface**

T-Zero™ is a visual, role based process sequencer that accommodates definition of one or more process flows that can be executed and interacted with much like one would with a real time Gantt chart. The T-Zero™ environment is aware of data and events received via umbilical, telemetry, ground instrumentation, and user input. In addition to providing self-documenting procedure execution and process state awareness for all role players it also automates decision making, constraint processing and state flow for operational command and control. Built-in safety interlocks can be defined to decrease reliance on manual monitoring and human reaction time.

### **Telemetry Acquisition Systems**

Telemetry acquisition systems are critical to understanding the performance of the launch vehicle in the critical flight phase. Downlink telemetry can provide information that can be used to support your payload customer, improve vehicle operation, and reduce the risk of future mission failure.

CCT has a great deal of experience integrating telemetry acquisition into launch vehicle, payload, and range operations. Unlike existing range systems that stovepipe these capabilities in disparate, complicated architectures, our approach is to integrate best-value COTS components that offer a modular architectural solution that is fully automated and pluggable with our command and control product line.

The CCT command and control product line includes an integrated plug-in for telemetry processing that provides seamless access to real-time vehicle data for subsystem status and event monitoring, tracking, control feedback for ground operations and launch sequencing, and post mission analysis. The fully integrated telemetry-processing module gives you the capability to fuse telemetry data with your other mission data sources (umbilical, weather, fueling, radar, etc.) without incurring the added cost and complexity associated with dedicated 3<sup>rd</sup> party telemetry processing systems.

### **Factory Operations Support**

There is an inherent process connection between launch site and factory operations. Vehicle systems are designed,

assembled, and tested at the factory to an intermediate stage of operational readiness, then transitioned to the launch site for final integration and launch preparation. Supporting the transition are the launch crew, a number of technical support specialists, and an array of tools and processes. The transition represents a significant part of the launch operations process with which CCT can help the LSP realize significant operational efficiencies with a supportive mission information management infrastructure.

A common ground architecture framework enables process and tools created for support of manufacturing and subsystem test and integration, to evolve and transition with vehicle integration and ultimately to the launch site. CCT's modular architecture isolates details of external interfaces and protocols from core processing services. Common automation elements such as graphical visualization, recording, and simulation are all modular in nature and can be plugged in like flexible building blocks, providing reuse, maintainability, and eliminating duplication of effort.

In additional, because CCT mission IT systems are network centric, it is possible to minimize the number of supporting personnel that have to transition to the launch site with the launch vehicle. Engineers can participate in launch operations and analyze mission data remotely from their office desktop.

### **Simulation and Training**

Another key element of the launch operations enterprise, and a central part of CCT product line strategy, is a comprehensive approach to mission simulation; one that supports vehicle component development, bench testing, subsystem/systems integration, as well as end-to-end mission simulations and dress rehearsals.

A robust simulation capability can facilitate timely integration of vehicle systems via missing element models, serve as the master regression test fixture for ground systems, and enable adaptive operations crew training. A simulation strategy is enabled by appropriate consideration within the infrastructure architecture, providing flexible modeling methods, and ease of integration of models with checkout, and decision support systems. CCT has integrated these fundamental simulation capabilities in to our products as a standard product feature. Simulations can be introduced in to operational systems such that operators, supporting application software, and visual displays are unaware whether they are interacting with live or simulated systems.

Our modeling engine allows a systems engineer to quickly create interactive models using a point and click GUI or high level scripting language. The modular and open nature of the simulation environment allows simulations to be scalable in their fidelity such that they can operate stand alone, or integrated with other models to create large-scale mission models. A programming library is also

available that supports the integration of 3<sup>rd</sup> party modeling tools or custom developed software models.

### **Flexible Support Approaches**

CCT can provide support the LSP in a variety of ways. CCT can provide engineering support on an hourly basis to provide niche resources when required or we can become part of your systems engineering and development team. CCT is also experienced in delivering turnkey solutions on a fixed price or on a time and materials basis.

## Case Study - Complex 20 Launch Control System

With an eye on breaking the mold at Florida's Cape Canaveral Spaceport, the Spaceport Florida Authority and the Air National Guard has created a new launch complex to test new "minimal launch campaign" operations concepts. Developed at Launch Complex 20 (SLC 20), an old Titan II pad just south of the towering EELV complex, the new facility will host suborbital launches from a 50,000 pound launch rail with minimal oversight and infrastructure. The Authority's goal is to provide a world class launch capability at an affordable price. The Air Force is supporting the high profile initiative by providing funding and Pathfinder launch vehicles.

CCT provided the launch control system for Complex 20 using our COTS Command and Control Toolkit™ software and recently released T-Zero™ sequencer technology. The integrated system supports vehicle tracking, vehicle telemetry acquisition and processing, control of facilities systems, launch rail control, and data monitoring capabilities.

The Command and Control Toolkit™ software is an ideal solution for SLC 20 because it is specifically designed to integrate diverse multi-mission, multi-user applications. The software also provides the common core around which application-specific modules and tools are integrated to produce turnkey systems.

CCT designed and implemented the Phase I launch control system (LCS) for SLC-20 to support the launch of the Terrier/ASAS vehicle from pad B. The system architecture supports expansion to pad A and a vehicle integration facility.

SLC-20 features a launch rail capable of launching rockets rated at up to 50,000 pounds of thrust. This photo shows a Starbird vehicle mounted on the launch rail.



Based largely on commercial products, the final system will support:

- Automated Countdown Sequencing
- Ignition Control, including safe, arm, and hold-fire
- Mission Planning/ Design
- Countdown Time Management
- Umbilical and Power GSE Control & Monitoring
- Range Ready Interfaces
- Real-time and Historical Archive and Retrieval
- On-screen Video Capability
- Simulation Tools for Testing and User Training

The system uses a client/server architecture distributed across three functional layers to optimize processing and increase system reliability and determinism. This approach groups similar forms of data processing and minimizes the need for complex interfaces and protocol transition. All layers are integrated across open interfaces that can be configured to a scalable variety of transport protocols, including Ethernet, FDDI, and ATM. This configuration can also be packaged for portable operations by configuring the Real-time Control Server (RTCS) in a high-end laptop or suitcase computer configuration.

The RTCS is the central control and monitoring engine for the system, hosting the mission-critical control and monitoring applications, including the T-Zero™ sequencer program and the interfaces necessary to connect them to other LCS subsystems and external systems.

The CCTK application environment provides data, command, and event software services for executing control and monitoring algorithms and serving graphic workstation clients with real-time graphical displays. Vehicle and ground data is acquired and decommutated from external system interfaces, time tagged, and multiplexed into a normalized sequential time ordered data stream by the RTCS front-end interfaces. Raw data is received and processed by the RTCS where it is converted to engineering units, linearized, limit checked, fused, recorded, and made available to the application environment.

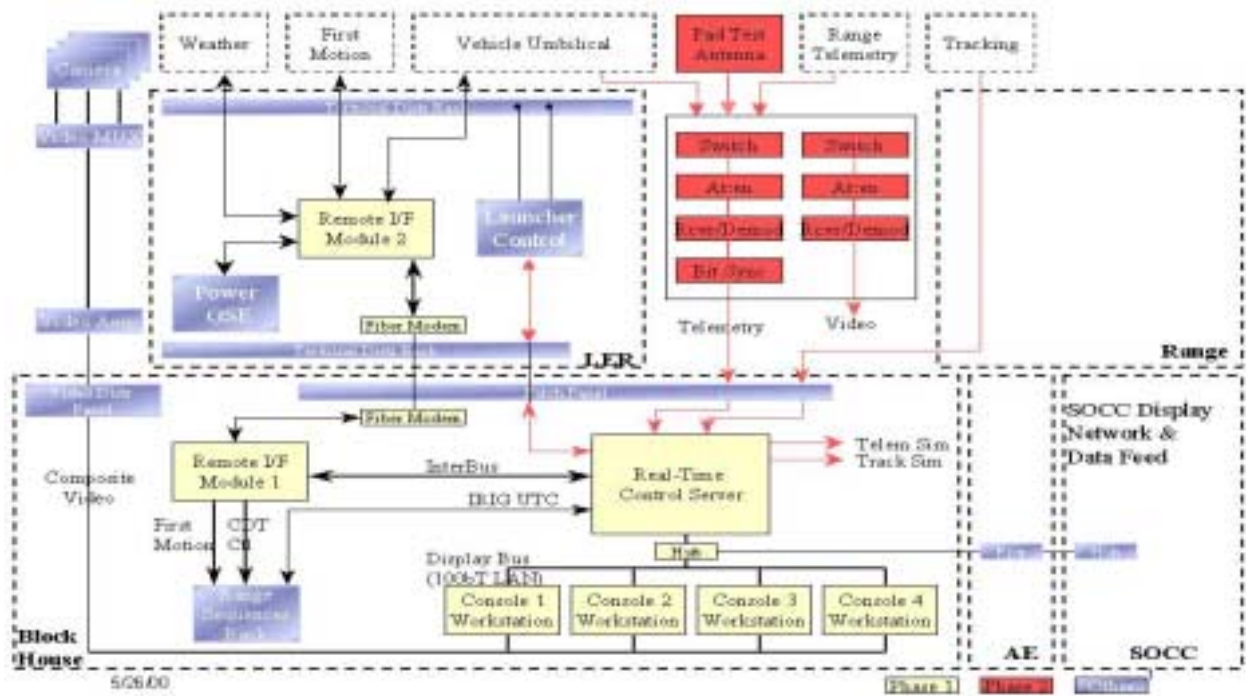
The toolkit software also provides a real-time web server option that allows all graphical displays to be viewed over the Internet in real-time. This allows support personnel to remotely monitor launch operations via a standard desktop browser.

Future options for Spaceport Florida include a tracking instrument simulator that will allow the system to conduct realistic mission dress rehearsals, operator training, and recreate past missions for demonstration purposes. Another possible extension is the plug-in Spaceport RangeNet™ range safety software for algorithmic processing of tracking data. The Spaceport RangeNet™ tool provides derivation of present position and instantaneous impact point data with a visual real-time decision support mechanism for analyzing actual vehicle performance verses planned performance.



The SLC-20 launch center requires only four launch controllers using highly automated multi-mission technology provided by CCT.

Command and Control Technologies Corporation specializes in launch site automation for government and commercial space programs. CCT provides turnkey solutions by integrating commercial hardware and software with custom software as required to provide tailored solutions for our customers. Visit our web site at [www.cctcorp.com](http://www.cctcorp.com), e-mail us at [info@cctcorp.com](mailto:info@cctcorp.com), or contact Pete Simons at (321) 264-1193 x103 for more information.



Launch control system architecture, comprised of distributed subsystems