White Paper

2nd and 3rd Generation Spaceport
Integrated Command and Control Concepts and Technologies

Including:
In-Line Direct Functions
Off-Line Support Functions
In-Flight Functions
and
Networks, Protocols, Standards and Communications / Data Handling
COTS / End Items / Components
Integrated Vehicle Health Management (IVHM) – Ground Segment

The Vision Spaceport Project

Kevin Brown, Command and Control Technologies Corp.
Edgar Zapata, NASA KSC

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Abstract

Second and third generation space transportation will require Spaceport command and control (C2) systems capable of supporting flight rates one and two orders of magnitude higher than current systems. Flight rates on the order of 1 or more flights per day are envisioned. This is also required to enable such enterprises such as Space Solar Power. In addition to productivity, the affordability of such systems must also be improved versus current implementations. Costs to acquire implement and operate spaceport command control architectures must improve.

The objective is the development of approaches that integrate multiple technologies that must work in unison in order to create future command, control, spaceport services, and traffic systems that are affordable, flexible, responsive, interoperable, and easily reconfigured, modified, and upgraded. This includes determining requirements, technology development, standards, and multi-site integration needs for comprehensive C2 systems that control the entire spaceport.

This enables the broad and affordable implementation of industry standards for COTS (commercial off the shelf) end items / components. This enables overcoming barriers to affordability in current systems, such as multiple differing protocols, standards, software architectures, and information exchange formats.

Background

Spaceport C2 systems as envisioned here addresses the integration of diverse systems:

In-Line Direct Functions

- In-line checkout, command and control systems, including flight vehicle landing, turnaround, integration (as required), and launch.

Off-Line Support Functions

- Off-line spaceport support services, including mission planning, ground activity scheduling, payload processing, logistics and administrative functions.

In-Flight Functions

- Flight operations, including space traffic control (range), in-flight operations and flight to ground interactions. This includes telemetry (such as integrated vehicle health management (IVHM), and communications), tracking and air/space coordination.

In order to achieve 2nd Gen goals of 1 week between launches (at $1000/lb costs) and 3rd Gen goals of 1 day between launches (at $100/lb costs) major challenges in real time and remote, command, control, monitoring, and automation will be required. As a benchmark, if such functions today are roughly in the ~$100’s of millions[2] of dollars to operate (Shuttle figures, not counting acquisition) then these systems will need to evolve to costs no greater than this value, but with much increased flight rate capability, first from less than once per month, to once per week and then daily.

Earth to orbit space transportation systems objectives of 1+ flights per day at about $100 per pound costs will require significantly improved spaceport command and control architectures. At these flight rates and with vehicle reliability of four 9’s (2nd Gen) to six 9’s (3rd Gen) the evolution of range to an elimination of destruct requirements will result.

Nonetheless, evolutionary approaches are required to continue to integrate the host of other spaceport systems, as well as range, within an integrated context leading to architectures that will achieve this end state. These include checkout and control systems (including launch), support functions such as flight planning, payload accommodation, flight and ground operations, and traffic management.

Description of Concept/Technology Improvement

The objective is the development of approaches that integrate multiple technologies that must work in unison in order to create future command, control, spaceport services, and traffic systems that are affordable, flexible, responsive, interoperable, and easily reconfigured, modified, and upgraded. This includes determining requirements, technology development, standards, and multi-site integration needs for comprehensive C2 systems that control the entire spaceport.

This development of this area / proposal requires:

- A process for identifying requirements across the entire spaceport.
- A roadmap for expanding C2 capabilities to handle all the functions identified.
- Designation of individual technology needs within the roadmap.
- Designation of standards, both existing and future, within the roadmap.
- A process for integrating C2 across multiple spaceports and spaceliners into the national airspace system.

Areas that require definition and development of *integrated architectures* for the unique requirements of 2nd and 3rd Gen (Spaceliner) type operations include:

In-Line Direct Functions

- Automation of checkout and control, including turnaround, servicing and launch operations
  - Process Automation Tools – Reduce dependence on custom software that permeates today's launch sites.
  - Integrated Vehicle Health Management (IVHM) - Ground segment – Techniques for identifying in-flight failures quickly, for quickly isolating the causes, for generating tasks for corrective work activity, for identifying overall system health (i.e. positive identification of lack of failures or lack of need for maintenance), and for communicating such information to the ground infrastructure are required.

Off-Line Support Functions

- Integration of planning, scheduling, automated diagnostics and maintenance / logistics systems
  - Real-Time decision support, in areas such as range safety, planning and scheduling, weather prediction-related decisions, launch sequencing, and aerospace traffic management. Use of automated mission planners, configuration controllers, instrument controllers, tracking solution selectors, smart vehicle monitors.

In-Flight Functions

- Air-Traffic Control and Management System
  - Pre-flight flight plan/object generation, processing, and approval
  - In-flight clearances and flight plan modifications
  - Distributed air/ground responsibilities and data link communications
  - Multi-sensor surveillance (e.g., primary/secondary radar, Automatic Dependent Surveillance)
    - Integration of weather forecasting, image processing
  - Satellite navigation
  - Trajectory modeling and conflict probing

- Air Traffic management & control system integration
- Dynamic special use airspace allocation
- Collision avoidance & situational awareness

Common

- Compatible interfaces, data architectures and information exchange standards
    - Adaptable, flexible system architectures, open to new and unanticipated functions
    - COTS systems, low acquisition costs through industry standard systems
    - Software structures for ease of code generation and verification reducing lines of code for new applications or spaceport growth and modifications.
- Common launch and flight control equipment for different vehicles
- Network Architectures
    - Distributed systems, global presence and mobile C2. As more functions migrate beyond physical proximity to the spaceport these systems technologies / networks and standards will need to be integrated into the in-line spaceport infrastructure
    - Communications (voice and data)

Component / Sub-Technologies

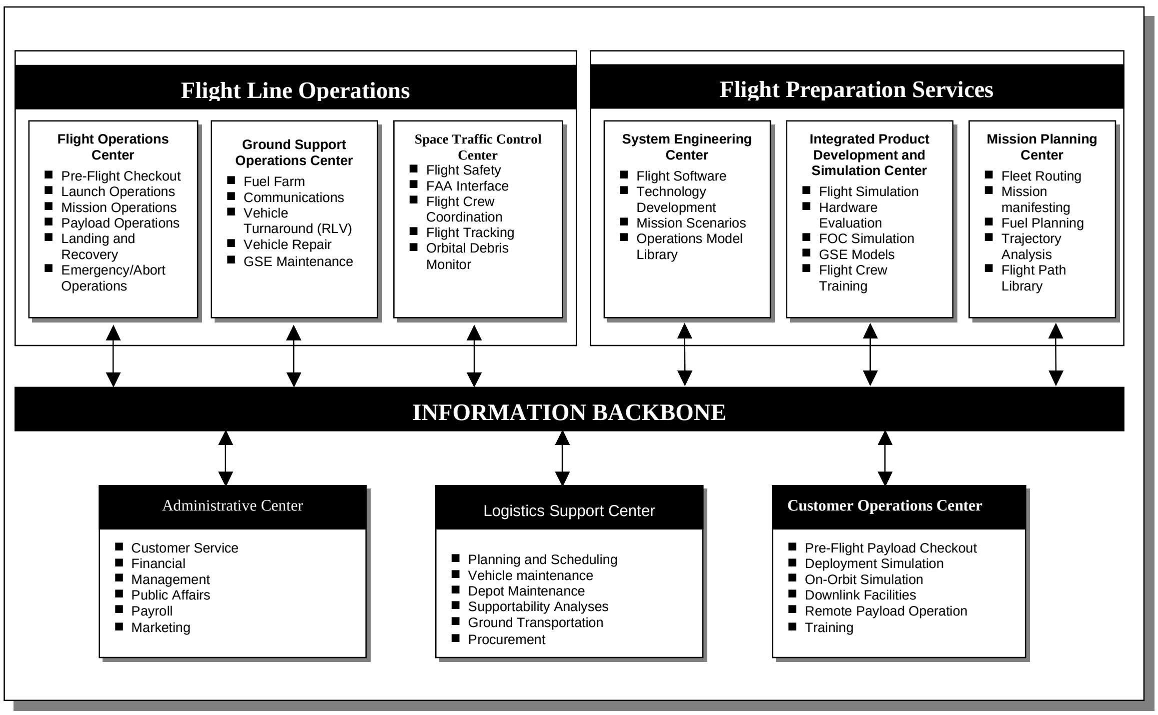
Major component / sub-technologies of an integrated C2 spaceport infrastructure include:

- Networks, Protocols, Standards and Communication / Data Handling:
    - Standards: Industry-wide standards that allow multiple vehicles and spaceports to communicate with one another are needed to enable efficient operation of diverse vehicles and launch sites. XML, extended markup language, is a promising technology that could form the basis for such a standard. Creation of a "spaceport markup language," based on XML, would facilitate exchange of information between vehicles and the ground. In this scenario, new vehicles would need a "data translation document" allowing them to communicate with the entire ground infrastructure. This would eliminate many of the issues associated with mission to mission reconfiguration, and integrate manufacturing sites, engineering centers, simulators, and launch and landing sites.
    - Common communications protocols: Closely related to the standards described previously, a spaceport operations communications framework is needed to define standard communication protocols between spaceports and launch vehicles, and between multiple spaceports. Roughly analagous to the international "Open Systems Interchange" model (sometimes associated with the X.25 and/or TCP/IP technologies) and the proposed SOIF reference model for inter-spacecraft communication (see ftp://ftp.estec.esa.nl/pub/ws/wsd/ccsds/ccsdsoif/refmodv1.doc), a spaceport reference model would allow different spaceports and launch vehicles to exchange information in a standard way, regardless of their

respective internal architectures. This approach provides designers much more flexibility while facilitating interoperability.

- COTS / End Items / Components: The broad implementation of industry standards for COTS (commercial off the shelf) end items / components enables overcoming barriers to affordability in current systems, such as multiple differing protocols, standards, software architectures, and information exchange formats. Areas include sensing (temperature, pressure, flow, loads, position, speed, etc) as well as control (actuation, pneumatic, electric, valves, etc).
- Integrated Vehicle Health Management (IVHM) - Ground Segment: Techniques for identifying in-flight failures quickly, for quickly isolating the causes, for generating tasks for corrective work activity, for identifying overall system health (i.e. positive identification of lack of failures or lack of need for maintenance), and for communicating such information to the ground infrastructure are required.

Concept Diagrams



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Reference

1. Brown, Kevin R., (1995) "A Ground Information Infrastructure for Spaceport Operations," 1st International Symposium on Reducing the Cost of Spacecraft Ground Systems and Operations".
2. Vision Spaceport (NASA, Boeing, Lockheed Martin, Command and Control Technologies (CCT), Barker-Ramos and Associates Inc., University of Central Florida, a Joint Sponsored Research Agreement) data, as distilled from various sources, NASA.