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RANGE INFORMATION SYSTEMS MANAGEMENT (RISM) PHASE I REPORT

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Executive Summary

Introduction

The National Aeronautics and Space Administration (NASA) is investigating alternative approaches, technologies, and communication network architectures to facilitate building the Spaceports and Ranges of the future. These investigations support the Second Generation Reusable Launch Vehicle (2nd Gen RLV), and other associated craft presently under development in Government, academic, and private sectors, and provide a national centralized R&D forum for next-generation Spaceport and Range technology development. These sectors all share the common goal of changing the historic risk/reward equation for access to space, with the intent to:

- Dramatically reduce launch cost
- Greatly improve launch system reliability
- Significantly reduce crew risk

The shared and tacit goal is to achieve routine access to space.

A fundamental paradigm shift is required to accomplish the desired goal. The historical approach of using dedicated and custom Range equipment situated at relatively few and widely dispersed Spaceports as the only access to space must change before routine access to space can occur. This change is analogous to the historical transformation that occurred in aviation; moving from dedicated, remote test sites where test pilots first experimented with jet-propelled aircraft to today's thriving international and regional airports.

Information networks at Spaceports and Ranges must transition to a total integration of existing, new, and emerging technologies that provide a new and robust way of interconnecting the Range assets, Range operations, and Range users during the launch event. This paradigm shift must occur despite the legacy of how the networks have evolved to this point. Instead of the dedicated, immobile, inflexible information infrastructures of today's Ranges and Spaceports, a more flexible (i.e. space-based) approach is needed. Implicit in this flexibility is the need for modularization, to allow incorporation of newer technologies not yet imagined, without requiring scrapping future systems not yet even defined. The key is to envision a transition to a Space Based Range Distributed Subsystem.

To accomplish this, the Range Information Systems Management (RISM) research task is providing a keen vision of both near and more distant future technologies in support of NASA's Advanced Range Technology Working Group (ARTWG) and the Advanced Spaceport Technology Working Group (ASTWG). Consistent with the goals originally identified for RISM, while supporting these working groups; this technical report details the results of researching and documenting the technical needs and technical characteristics of future Ranges, Range systems, and Range users. This report explores

extant and emerging technologies and identifies the characteristics and likely requirements of a future Space Based Range Distributed Subsystem based on these technologies. This report is but the first step in implementing a future Space Based Range (SBR) Distributed Subsystem to support the Spaceports and Ranges of the future and to provide the infrastructure to enable routine access to space.

The Vision

Before commencing the development of communication systems for future Spaceports and Ranges, a vision is necessary, for as one Japanese proverb states, “Vision without action is a daydream. Action without vision is a nightmare.” Further, as a classic Spanish play cautions, “... dreams are only dreams.”¹ To accomplish the desired goals, it is vital to provide a carefully crafted vision upon which a cost-effective plan for action can be built.

Vision, though, is more than the mere avoidance of ‘night-dreams’ or nightmares. It is also the food that nourishes mankind’s collective restless soul to explore beyond known scientific frontiers. Without a vision, expansion beyond existing scientific frontiers stops, for “Where there is no vision, the people perish.”²

The vision for Range Information System Management (RISM) is to provide a largely invisible infrastructure, supporting the following goals:³

- Implementing an interoperable network that supports future generation vehicle operations without requiring reconfiguration
- Supporting critical decision processes to insure public, crew, vehicle, and mission safety
- Meeting the security, reliability, and availability needs by providing communication capability to any vehicle; worldwide, 24/7, manned or unmanned
- Providing data throughput capability for meeting the real-time, on-demand, and timely information needs of the future with minimal latency
- Integrating functionality across the Space Based Range (SBR) Distributed Subsystem, including Spaceport Range Systems (SRS), Weather Instrumentation and Systems (WIS), Decisions Models and Simulation (DMS), and the Space Based Range (SBR) consisting of terrestrial, satellite, and vehicle components

¹ The ending is “y los sueños, sueños son.” in the verse “¿Que es la vida?” in the famous play “Life is a Dream” by Golden Age Spanish dramatist Pedro Calderón de la Barca (1600 - 1681).

² Proverbs 29:18

³ Much as the average passengers on airliners today are largely unaware of the behind-the-scene infrastructure of Air Traffic Control, Ground Control, maintenance, and communication networks, the goal for RISM is to achieve the same degree of tacit functionality. With this level of advancement, all communication needs are transparently met, and no burden is placed inordinately on any one vehicle or on any one particular Spaceport.

A vision is likely to remain just a daydream, or at worst, a ‘night-dream’, unless it is communicated to others. Communicating a shared vision to aerospace leaders from Government, industry and academia is especially critical for the success of this research, and to promote the development of communication/data architectures and advanced distributed networks that meet the needs of concurrent and future generations of Spaceports and Ranges. To support communicating this vision, a working group, the Space Based Range Distributed System Working Group (SBRDSWG), was formed as part of the NASA-funded RISM task order in the spring of 2002. This working group was subsequently renamed the Future Integrated Range and Spaceport Technology Working Group (FIRSTWG) at the conclusion of the RISM Phase I Project, to reflect better its inclusion of multiple technologies in response to an evolving understanding of changing communication needs. The numerous contributions from the members of the SBRDSWG, now FIRSTWG, in response to a shared vision communicated through bi-weekly technical exchange, permeate the information contained in this report.⁴ Without the extensive support of these numerous aerospace leaders, this report could not have been written.

Summary of Conclusions

During the RISM Phase I Project, the RISM team, comprised of:

- NASA and NASA-contractor engineers and managers, and
- Aerospace leaders from Government, Academia, and Industry, participating through the Space Based Range Distributed System Working Group (SBRDSWG), many of whom are also
- Members of the Advanced Range Technology Working Group (ARTWG) subgroups, and
- Members of the Advanced Spaceport Technology Working Group (ASTWG)

have together envisioned a future set of technologies for implementing future Ranges and Range systems that builds on today’s cabled and wireless legacy infrastructures while additionally seamlessly integrating both today’s emerging and tomorrow’s building-block communication techniques. As mentioned previously, the fundamental key is to envision a transition to a Space Based Range Distributed Subsystem. The further enabling concept is to identify the specific needs of Range users that can be solved through applying emerging communication technology.

⁴ Section 9.2 contains a list of the members of the SBRDSWG and their respective organizations.

As envisioned by these aerospace leaders, the future Spaceport and Range will constitute a single, global, communication and data-networking system, partially space-based, that will:

- Contain mobile, portable, and fixed elements
- Provide an always on, 24/7, communication environment
- Provide high bandwidths, achieved without wires or cables, that will form the majority of new extensions to today’s infrastructure, to permit flexibly accommodating change, and to avoid stuffing more physical cables into the crowded cable trays and ducts that exist today
- Be pervasively connected, in terms of linking wirelessly and without fibers (e.g., a “fiberless” extension to the existing infrastructure) nearly everything that is new or that is added to the Spaceport and Range environment
- Provide seamless connections to today’s wired communications infrastructure, as well as to future systems
- Provide Data Assurance, comprised of:
 - Data Integrity (i.e., protection against tampering, whether intentional or unintentional)
 - Data Authentication (i.e., anti-spoofing functionality)
 - Data Availability (which can range from minor latency issues (timeliness) all the way to data unavailability)
 - Data Ease-of-Use
 - Data Security (i.e., protection of data content to unauthorized personnel)

The overarching conclusion from the RISM Phase I activities, culminating in this document, is that future communication and data networking will largely grow from the communications baselines that exist today, although customized for ease of use within a Spaceport and Range environment. This approach is both desirable and feasible, in terms of managing costs, as well as for accommodating the desired functionalities; but missing details remain where early development must occur directly to empower the needed future technology growth.

For the buried fiber optic cables and much of the cabled and wireless infrastructure in place today, no recommendations are made; either for immediate removal or for wholesale ‘forklift’ replacements. Such an approach would be costly. Rather, the communication growth that is foreseen is, at least initially, strictly around the edge of the extant data networking and communication environment. Starting with what is often called the “First Mile” or “Last Mile” problem of traditional public communication networks, this document makes a strong case that three emerging technologies are likely to provide the majority of the technology additions needed to solve many communication problems, while additionally providing a future upgrade path that will counter obsolescence or performance issues. Wireless Ethernet (Wi-Fi), Ultra Wideband (UWB), and Free Space Optical (FSO) are the three disruptive and emerging technologies that can augment today’s communication infrastructure. These three technologies can provide performance over three decades of data rates, while augmenting communications in the near future and providing flexibility for future needs. However, a key caveat is

necessary. As they exist today, these three technologies are clearly not *yet* suitable for wide scale deployment on Spaceports and Ranges. In terms of their underlying strengths, and within the realm of where these technologies are headed, within the next five to ten years these technologies will likely become ‘industrial-strength’, having all the necessary attributes necessary to meet the combined requirements that will then be desired. Table E.3-1 lists the key attributes of these three technologies. Among these technologies, an assortment of data rates from less than 10 Mb/s to greater than 10,000 Mb/s, supporting operation over various distances, with a choice of power consumptions (as needed, for example, to select body-worn, battery-powered portable apparatus) are provided, thereby meeting communication needs for Range users over the next few decades.⁵

As presented in this document, the time to understand these three technologies and to slightly shift the commercial plans for their ongoing developments is now, while there is still time to inexpensively effect fundamental changes. To introduce desirable no-cost or low-cost features into integrated circuits (ICs) intended for mostly commercial product uses and presently being developed is entirely possible. Managing future life-cycle costs is often best done by managing technological developments. Once products are fully designed, adding any change is often not cost-effective, and at that point, the ability to affect life-cycle costs is long lost. It is possible, within only a narrow window of opportunity open over the next few years, to insert performance features for next-generation Wi-Fi, UWB, and FSO related ICs, into what are ostensibly commercial product ICs, since the recurring cost for Spaceport and Range features (once implemented into the ICs) is negligible.

The future, though, is not about the technology, although that is the focus of this document. Instead, it will be about the engineers, scientists, explorers, and visionary leaders who first enable the technology and who then use it. For this reason, this document additionally makes a strong case that for future communication and data networks to be effective, human interface engineering must be carefully considered. This is necessary to achieve ubiquity for effective interface devices. Once ubiquitous, the advantage of a standardized, efficient, human interface becomes even stronger. Technological novelty for the sake of novelty must not be introduced at the expense of effectiveness. Although specific technologies on Spaceports and Ranges may be replaced in the future, the important lesson from the past is that newly introduced technologies usually must continue to interface in familiar ways, to avoid confusing the human users. Achieving acceptance of new human engineering interfaces requires a keen understanding of numerous computer-based information topics, coupled with a deep appreciation of historical practices. For this reason, an historical review of technologies,

⁵ Although not discussed in this report, it is assumed tacitly that some functions, such as range safety and flight termination, by the virtue of their need not to rely on other communication networks, must, by necessity, remain isolated from other communication and data networks, while having nonetheless to interface with other communication systems. Still, it would be an intriguing idea to consider UWB for use in future flight termination command systems, what with UWB’s inherent selectable security and simplicity of implementation as compared to existing systems.

aerospace timelines, and communications timelines are included in this document; establishing a reference framework for introducing new technologies.

If success is ultimately to follow, whatever technologies are forthcoming in the near term, foreseen or not in this document; an underlying need will exist to keep human interactions smoothly integrated with the technologies. The writers and contributors to this document hope that the vision contained within this document enables humans to remain innately involved in achieving routine access to space.

Key Technologies for Communication Network Edge & Core Extensions

Technology Attribute	Wireless Ethernet (Wi-Fi)	Ultra Wideband (UWB)	Free Space Optical (FSO)
Location:			
Portable	X	X	X
Mobile	X	X	X
Fixed	X	X	X
Data Rate:			
Medium: <10 Mb/s – 100 ⁺ Mb/s	X		
High: 100 Mb/s – 1000 ⁺ Mb/s		X	
Highest: 1000 ⁺ Mb/s – 10,000 ⁺ Mb/s			X
Power Consumption:			
Low		X	
Medium			X
High	X		
Data Security:			
Low	X	X	
Medium	X (With planned extensions)	X	X
High	X (When merged with UWB)	X	X

1.0 **RISM PHASE 1 PROGRAM**

1.1 **INTRODUCTION**

1.1.1 **Historical Perspectives**

On May 29, 1947, with the memories of World War II still fresh in the minds of many, a major international event unfolded. The US Army was conducting tests of a captured German V-2 (Figure 1-1) at the White Sands, New Mexico, Rocket Ordnance Proving Grounds. During the test, control was lost and the rocket headed South instead of North, with the unfortunate result that a cemetery in Juarez, Mexico, was the final resting place of the wayward V-2. The accident investigation identified the cause of the errant flight as a cross wiring of the guidance system. Interestingly, this error was an exact repeat of an earlier error that had occurred at Peenemunde on June 13, 1944, in which another V-2 rocket under German control had crashed near the village of Knivingaryd, in southern Sweden. In both cases, Dr. Ernst Steinhoff was responsible for the guidance system and was the cause of the cross wiring errors.⁶ The incident made apparent to all that more positive Range safety was badly needed to corral errant rockets. Rockets were growing in their reach, with the risk increasing with each launch that an errant rocket could literally crash most anywhere on Earth if control were lost during launch.



Figure 1-1 German V-2 Rocket

⁶G. Harry Stine, ICBM (New York: Orion Books, 1991) pp. 84-85

The Cold War and nuclear proliferation were growing, too. On Christmas Day 1946, the first Soviet reactor had gone critical at the Kurchatov Institute in Moscow and the first Soviet atomic explosion occurred 29 August 1949 at Semipalatinsk Test Site, Kazakhstan, with a yield of 22 kilotons, of an exact copy of an earlier U.S. Gadget/Fat Man design.⁷ Clearly, if an errant rocket were to reach an area under the control of the Soviets, an unplanned escalation into a war, if not a nuclear war, could easily become the unfortunate outcome. The need for a more remote launch facility than the Rocket Ordnance Proving Grounds at White Sands, New Mexico, as well as the need for more positive Range control and containment functionality, was becoming evident to all.

President Harry S Truman established the Joint Long Range Proving Grounds at Cape Canaveral, Florida, in October 1949. Cape Canaveral was nearly ideal for testing rockets (Figure 1-2). It was lightly inhabited and nearly undeveloped. The weather was suitable for year-round testing, barring any stray hurricanes passing through the area during the annual hurricane season; and more importantly, the proximity to the Atlantic Ocean meant that rockets could be launched eastward, as would be needed for later orbital testing, without endangering populated areas. Furthermore, a string of islands fortuitously extending from Grand Bahamas Island to Ascension Island in the South Atlantic meant that tracking stations could be built, once they were needed.⁸



Figure 1-2 Early Bumper Launch From Cape Canaveral

⁷ <http://www.fas.org/nuke/hew/Russia/Sovwpnprog.html> retrieved May 20, 2002. Website was subsequently removed sometime prior to July 17, 2002; due to security concerns of controlling publicly available information on nuclear weapons post September 11, 2001

⁸ *The Kennedy Space Center Story*, NASA Public Affairs, 1991 Edition, <http://www-pao.ksc.nasa.gov/kscpao/kscstory/ch1/ch1.htm>

After the Joint Long Range Proving Grounds were established, the Air Force assumed control of the World War II training base at the nearby Banana River Naval Air Station located 20 miles (32 km) south of Cape Canaveral, and renamed it the Patrick Air Force Base. Here, in 1951, the Air Force established the headquarters of the newly created Air Force Missile Test Center, which included a Range. These facilities were renamed the Air Force Eastern Test Range in 1964. Another name change occurred for the Range in 1977, as the Eastern Test Range became part of Detachment 1, Space and Missile Test Center. Yet another name change occurred in 1979 with the renaming to the Eastern Space and Missile Center (ESMC). Since 1964, however, nearly everyone has referred to this Range as simply the Eastern Range.⁹

In the late 1950s, the beginning of the Western Range was established at Camp Cooke on California's coast, north of Los Angeles. In 1958, Camp Cooke was renamed Vandenberg AFB. Vandenberg AFB supports both polar launches and western launches of ICBMs. An additional range, known originally as the High Range, was established at today's Edwards AFB in the 1950's to support the X-15 rocket-powered aircraft program. Another range was developed at Wallops to test sub-orbital missiles and sounding rockets. At present, only the Eastern Range has a requirement to support manned launches. A lesser launch capability is also available at Kodiak, Alaska. Launches at Kodiak typically require installation of portable Range equipment for each launch.

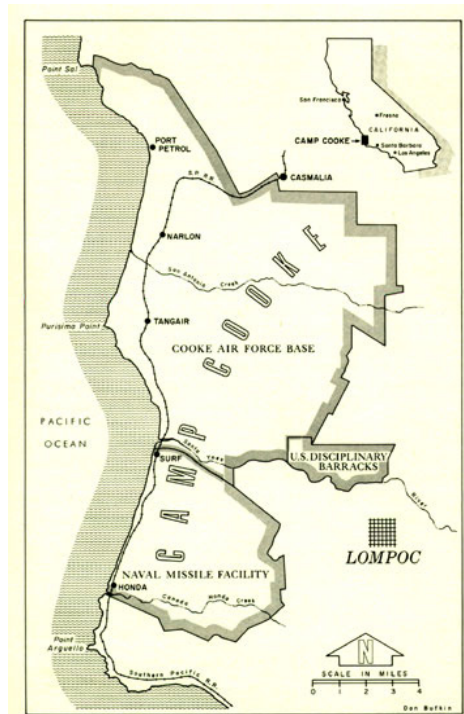


Figure 1-3 Camp Cooke In 1958

⁹ [The Kennedy Space Center Story](http://www-pao.ksc.nasa.gov/kscpao/kscstory/ch1/ch1.htm), NASA Public Affairs, 1991 Edition, <http://www-pao.ksc.nasa.gov/kscpao/kscstory/ch1/ch1.htm>

1.1.2 Changing Needs and Changing Perspectives

For nearly 50 years, the Ranges operated under a long-held policy of Government ownership and Government control. On September 28, 2000, the Space and Aeronautics Subcommittee, under the leadership of Chairman Rohrabacher, R-California, of the House Science Committee, held a hearing on the commercial space launch industry and the construction of new, private launch ranges. Edward C. Aldridge, Jr., Chairman, Defense Science Board Task Force on Air Force Space Launch Facilities and CEO, The Aerospace Corporation, testified before the U.S. House of Representatives Committee on Science Subcommittee on Space and Aeronautics. Key points from his testimony that pertain to RISM are:

- Access to Space must be recognized as a national priority.
- Space Launch Ranges are "National Assets".
- The future "vision" of the space launch ranges must address the combined needs of Government and commercial users.
- Existing Government Ranges are not "customer friendly".
- The National Airport System (NAS) has the most direct applicability to future concepts for modeling space launch range operations.
- New technologies can increase flexibility and reduce costs. Technology application (such as GPS navigation, Autonomous Flight Termination System, Satellite Telemetry Relay and improved weather forecasting systems) can play a large part in reducing future infrastructure costs by permitting the phase-out of old and expensive ground equipment and avoiding unnecessary weather delays.
- Sufficient information is now available to describe a vision for future range operations.

This RISM report uses the information available today to describe a vision for future range operations. This vision is one based on combining appropriate present technologies with a likely cadre of future technologies, that together will combine to form a total technology capability for the near and more distant futures.

1.2 WORKING GROUP

1.2.1 Description

As a part of the RISM effort, a need for a technical working group was quickly identified. Originally, this need was supported by the Advanced Range Technology Working Group (ARTWG) Communications Subgroup. Later a separate working group was created.

The new working group was created with participants from the following organizations:

- NASA – KSC
- NASA – Wallops
- NASA – other centers
- AF 45th Space Wing
- AF SMC/CWP
- Navy NOTU
- Range Engineering Contractor (SLRSC)
- FAA
- Aerospace Industry
- State Spaceport entities
- Academia

The original name for the working group was

SBRDSWG (Space Based Range Distributed Subsystem Working Group).

This was later changed to

FIRSTWG (Future Integrated Range & Spaceport Technology Working Group).

1.2.2 Vision Statement

The vision statement for the SBRDSWG / FIRSTWG is:

The Space Based Range (SBR) Distributed Subsystem Working Group, comprised of aerospace leaders from government, industry and academia will promote the development of Communication architectures and advanced distributed networks that meet the needs of existing and future generations of Spaceports and Ranges.

In support of this vision, it is the intent that the SBRDSWG / FIRSTWG:

- Will be the professional working group of choice for promotion, support, and evolution of advanced communication architectures and networks supporting the combined Spaceport and Range shareholder and partner community
- Will establish an organizational structure facilitating working group membership participation, with position rotation to preclude participant burnout
- Will support the enhanced growth of Range capability by providing a diverse and widely disseminated array of options; including distributed and multiprocessing systems, efficient protocols, Radio Frequency (RF), Laser, Fiber Optic, and additional communications links supporting of Spaceports and Ranges integrating new formats, usage, and data delivery options

- Will encourage members to lead in aerospace technology, participating in both scholarly and civic development communication of Spaceport and Range technologies. To accomplish this, the members should be diverse; with a broad range of knowledge and expertise, to enable clear and effective communication of Spaceport and Range capabilities and issues to a wide range of government, industrial, and public audiences

1.3 OBJECTIVES

The primary objective for the Range Information Systems Management (RISM) task is to lead the development of a Space Based Range Distributed Subsystem (SBRDS) network providing the concurrent features and growth capabilities necessary for future Spaceports and Ranges to interconnect Range assets, Range operations, and Range users during launch and recovery events.

SBRDWSG / FIRSTWG is a working group aimed toward addressing the day-to-day needs of Range workers who actually use the existing Range systems.

The primary goals of the RISM research and documentation effort are to:

- Proactively identify and provide reasonably accurate predictions for the evolving communications needs of the SBRDS
- Research, document and understand the equipment, operation, and processes of the current Range architecture
- Research and document the needs and characteristics of future Ranges, Range systems, and Range users
- Research and document technologies that could be associated with future ranges, space operations and information systems
- Identify the characteristics and requirements of a future SBRDS to meet the needs and desired characteristics of future Range users
- Identify the terrestrial, satellite, and vehicle components necessary to interconnect Spaceport Range Systems (SRS), Weather Instrumentation Systems (WIS), Decisions Models and Simulation (DMS), and Space Based Range (SBR) elements; permitting them to communicate with one another, with test and processing facilities, as well as with space vehicles
- Identify communication system architectures that will provide real-time information, on-demand, with minimal latency, to support critical decision processes; insuring public, vehicle, crew, passenger, and mission safety

RISM further seeks to multiply the knowledge base of the in-house investigators through participation in the active efforts of:

- SBRDSWG / FIRSTWG
- ARTWG

- ARTWG Communication Subgroup
- ARTWG other Subgroups
- ASTWG (Advanced Spaceport Technology Working Group)
- ASTWG Subgroups

ARTWG is a collaborative NASA/US Air Force/Industry/Academia effort to focus interest and investment in Range technologies (Figure 1-4). It is co-chaired by NASA and the US Air Force, and comprised of aerospace leaders from industry, academia, and national, state, and local governments. ARTWG is a multi-layer (Figure 1-5) organization with functional subgroups as its base. ARTWG addresses Range (Figure 1-6) development needs while its companion organization ASTWG (Advanced Spaceport Technology Working Group) addresses Spaceport development needs.



Figure 1-4 ARTWG National Development Strategy¹⁰

¹⁰ <http://artwg.ksc.nasa.gov/>

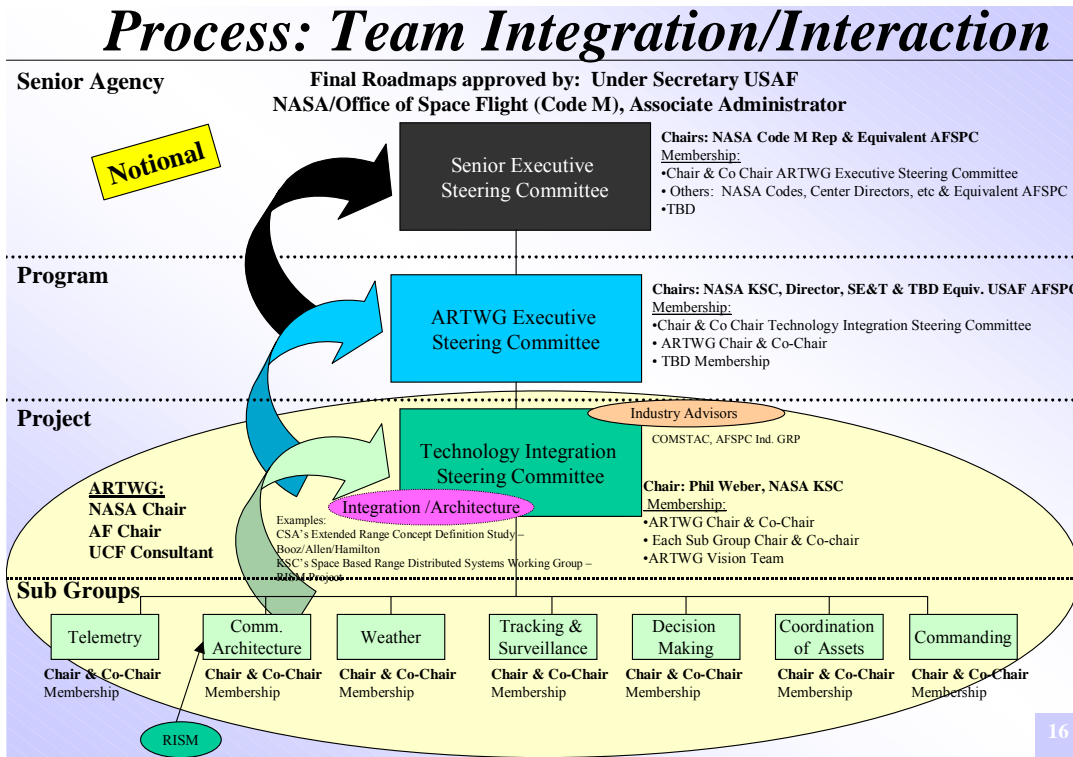


Figure 1-5 ARTWG Integration / Interaction Process

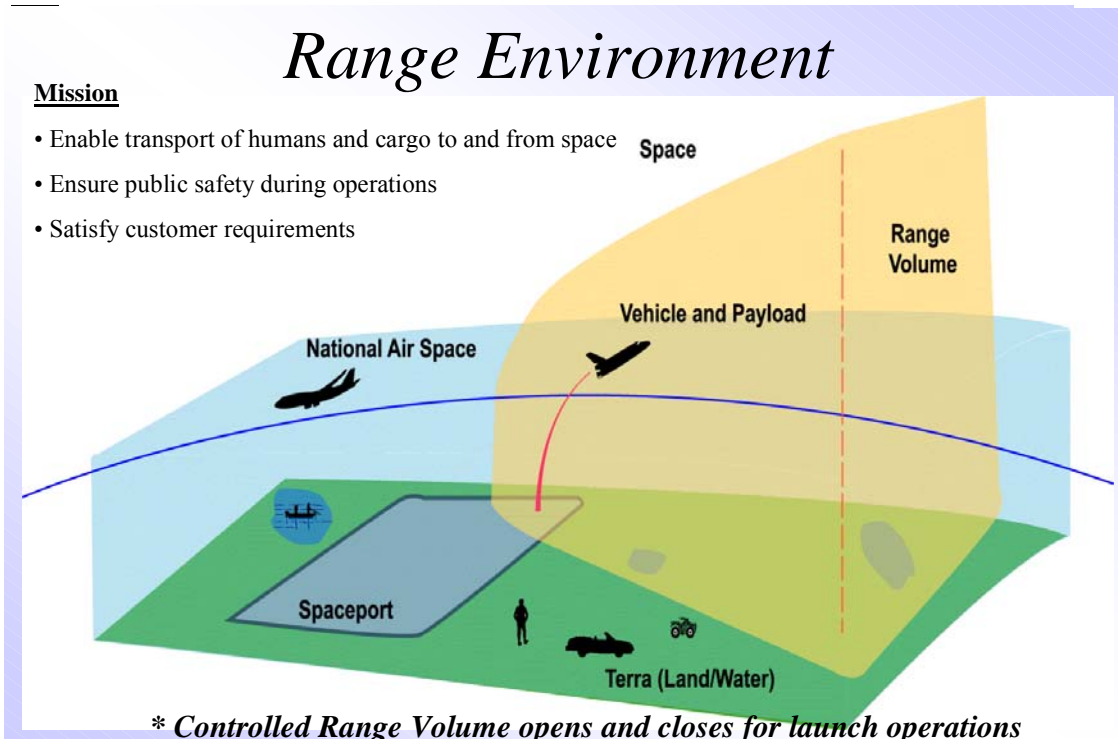


Figure 1-6 Spaceport And Range Environments

1.4 SCOPE

Activities associated with RISM during Phase I will provide:

- Identification of technologies that should provide the greatest long term return on investment for the U.S. space program and its associated industries without prematurely choosing winners and losers; this includes identification of technology gaps
- Equitable and open access to technical and administrative information wherever possible, while simultaneously meeting mission security, safety, and reliability needs
- Service to the planned users of future Spaceports and Ranges
- Cooperation, collaboration, and resource sharing to increase reuse of ARTWG and ASTWG generated data and resources
- Redundant Spaceport and Range communication capabilities when needed to improve reliability and safety for the public, shareholders, and partners
- A global perspective supporting the national needs of the United States while facilitating international use of Spaceports and Ranges within the United States through providing a well documented interface to the SBRDS

Additional goals of the RISM participants in the ARTWG and ASTWG are to provide:

- A clear, strategic vision of the goals desired for RISM
- Conservation and preservation of communication architecture and telemetry architecture trade studies performed during RISM
- Widespread dissemination of all information necessary to support the needs of shareholders and partners
- Education of potential users to the technology capabilities initiated, developed, and expanded through the transition to a Space Based Range (SBR) Distributed Subsystem
- A collaborative participation in the ARTWG and ASTWG permitting easy identification of disruptive¹¹ technological breakthroughs improving mission reliability and efficiency wherever possible, thus improving safety for the public, vehicle, crew, and passengers
- Timely research into alternative communication techniques and communication network architectures that best support initial communication needs while providing long-term growth potential

¹¹ Disruptive technologies refers to those new discoveries that represent an order of magnitude improvement of existing technology and which eventually replace the present technology.

1.5 STRATEGIC PLANS

To support the goals and aims of the RISM development effort for a future Space Based Range (SBR) Distributed Subsystem, the following six strategic plans, and enabling goals for each plan, are identified:

Strategic Plan 1.0

The Working Group recognizes the contributions that academic, industrial, and governmental members make in support of future Spaceports and Ranges by communicating Spaceport and Range technologies via their involvement in higher education, scholarly communication, and civic development to ensure public, crew, passenger, vehicle, and mission safety of space vehicles.

Enabling Goals

- Working group members understand their roles as information leaders in their respective institutions.
- Working group members understand the need for the timely, open information sharing to resolve issues as quickly as possible, improving work accomplishment rates and the quality of work accomplished.
- Working group members will promote an atmosphere in their respective institutions that, wherever possible, encourages the consideration of disruptive technological breakthroughs capable of improving mission reliability, safety, and efficiency.
- Working Group Members understand the need for timely resolution of open issues, thereby reducing budget waste, improving the “bang-for-the-buck” of RISM funding.

Strategic Plan 2.0

Non-governmental working group members may serve as advocates for public policy, legislation, and institutional changes that enhance the values and contributions they make to Spaceport and Range technology.

Enabling Goals

- ARTWG improves its ability to function as an authoritative and influential advocate for introducing modern equipment onto the Ranges, replacing the aging legacy hardware.
- ARTWG enhances the visibility, credibility, and favorable resolution of issues affecting Spaceports at the federal, state, and local levels.
- Academic and industrial working group members' skills are developed and the ability of these working group members to implement institutional change and improve existing Range practices enhanced.
- ARTWG activities increase collaboration and coordinate the efforts of the Spaceport Technology Center of Excellence goals with other NASA Centers and existing and potential Launch Sites.
- ARTWG strengthens its partnerships with other aerospace-related, governmental, and higher education organizations.

Strategic Plan 3.0

RISM is an inclusive development effort serving governmental, industrial, and academic working group members as well as aerospace professionals working in related fields in support of Spaceports and Ranges

Enabling Goals

- RISM participation within ARTWG/ASTWG/SBRDSWG/FIRSTWG continues to include working group members from diverse populations, facilitating effective communications with various governmental, industrial, and academic organizations having varied backgrounds.

Strategic Plan 4.0

Governmental, Industrial, and Academic working group members are continually engaged in learning for their own professional development and growth.

Enabling Goals

- Leadership skills among all working group members are strengthened. "Every working group member a leader" is fully realized.
- Governmental working group members are effective and productive professionals, who make significant contributions to their respective governmental organizations and working group membership, and who, through their involvement in the working group, promote trust of government employees by exhibiting and supporting sound policy-making and cost-effective follow-through.
- Industrial working group members are effective and productive professionals who make significant contributions to their respective organizations and working group membership, and who support the development, production, and introduction of cost-effective technologies, whether established or disruptive, in support of the goal of reducing \$/lb to orbit, providing increased launch opportunities.
- Academic working group members are effective and productive professionals who make significant contributions to their respective organizations and working group membership, and who support the higher education of their students on Spaceport and Range issues, thereby teaching the future workers-in-training, who will run the Spaceports and Ranges of the future.
- All working group members are encouraged in the development of their scholarly research skills through training and nurturing and providing mechanisms for publishing.
- All working group members will support the enhanced growth of Range capability through a diverse and widely disseminated array of options involving distributed and multiprocessing systems, efficient protocols, Radio Frequency (RF), Laser, Fiber Optic, and additional communications links in support of Spaceports and Ranges, integrating new formats, usage, and data delivery options.

Strategic Plan 5.0

RISM is a national, interactive supporter in creating, expanding, and transferring the body of knowledge of Spaceport and Range technology to its working group membership, and hence, to the general aerospace community with a need to know.

Enabling Goals

- RISM firmly supports its position as a leader in aerospace technology for Spaceports and Ranges.
- The speedy dissemination of research and effective practices among governmental, industrial, and academic working group membership is increased.
- Research that involves all of the SBRDS supporting organizational units is expanded and supported so that the value of contributions made is demonstrated.
- Collaborative research and developmental projects that may involve risk, but whose results promise to make a positive difference to the goals undertaken for SBRDS, are developed and supported.
- Security is maintained through the control of information regarding range destruct information to a strict ‘need-to-know’ basis.

Strategic Plan 6.0

The ARTWG/SBRDSWG is an effective and dynamic organization that continually enhances its capacity to create its future and assess and improve its performance in carrying out its mission.

Enabling Goals

- Data about member and nonmember needs and requirements for Spaceports and Ranges is collected and analyzed within RISM on a regular basis. Action Items are generated, and progress is tracked against them, to address and meet the needs and requirements necessary to provide increased launch opportunities and to reduce the cost of operations by providing standardized services with minimal reconfiguration.
- Relevant benchmarks to which the ARTWG/SBRDSWG/FIRSTWG membership aspires are established.
- Assessment and evaluation of ARTWG/SBRDSWG/FIRSTWG meetings, telecons, and activities are expanded.
- ARTWG/SBRDSWG/FIRSTWG audits are conducted and the organizational structure is regularly reviewed to determine if it lends optimal support for accomplishing the strategic plans desired.
- Positions within the ARTWG/SBRDSWG/FIRSTWG are rotated on at least an annual basis to prevent participant burnout while performing the day-to-day work of his own organization.
- The strategic planning process for the association becomes an integral part of operations and member leader activity.

2.0 TIMELINE SUMMARIES

Timelines are convenient tools for giving a quick insight into how a particular technology is evolving. This section summarizes timelines for both the Aerospace and Communications technologies. The more detailed timelines for both of these technologies are included in Appendix A.

Unlike the Communications Timeline presented later in this document, the following aerospace timeline covers a much shorter period of not quite one century. The history of aerospace flight certainly precedes the 20th Century, but the earlier history before the Wright Brothers' famous flight in 1903 is largely discontinuous with much of the progress over the last century, the balloon flights by the brothers De Montgolfier, Joseph and Etienne, in 1783, notwithstanding.¹²

Communications technology, on the other hand, still uses techniques that date, in many cases, nearly to pre-history, and which provide considerable guidance for envisioning communication systems of both today and tomorrow. Hence, the Communications Timeline covers a much longer period.

Relative to future Spaceports and Ranges, an historical perspective commencing with the Wright Flyer best illuminates the trends of aerospace flight necessary for purposes of gaining an understanding of future likely trends.

¹² <http://www.allstar.fiu.edu/aero/montgolgiers.htm>

2.1 AEROSPACE

Table 2-1 presents a timeline of key aerospace-related events that are of importance to future Spaceports and Ranges. These are the major milestones, which changed man's perception of aerospace flight most drastically. This list is by no means meant to be comprehensive; rather, its purpose is merely as a necessary prologue for understanding future trends and for envisioning and understanding likely Spaceport and Range needs of the future. A more detailed timeline of key aerospace events is included in Appendix A.1.

Table 2-1 Aerospace Timeline of Significant Events

Date	Events	Range	Vehicle
12/17/03	Wright Brothers - First powered flight	Kitty Hawk, NC	Wright Flyer
3/16/26	Robert Goddard tests worlds first liquid fuel rocket	Auburn, MA	
5/20/27	Charles Lindbergh - first solo, nonstop transatlantic flight	Atlantic Ocean	Sprit of St. Louis
10/14/47	Chuck Yeager - First supersonic flight	Edwards	Bell X-1
7/24/50	First launch from ETR	Cape Canaveral	Bumper 8 (V-2 + Corporal)
10/4/57	Sputnik launched	Russia	R-7
1/3/58	Explorer-1 First US launched satellite in space	Cape Canaveral	Juno-1
10/1/58	NASA formed out of NACA		
4/1/59	NASA selects original 7 astronauts: Carpenter, Cooper, Glenn, Grissom, Schirra, Shepard, & Slayton	Cape Canaveral	Mercury
4/12/61	Yuri Gagarin - first man in space	Russia	Vostok
5/5/61	Alan Shepard - First US manned flight (sub-orbital) - Mercury	Cape Canaveral	Redstone
5/25/61	Kennedy's challenge to go to the moon	Cape Canaveral	
11/22/63	President Kennedy Assassinated		

Date	Events	Range	Vehicle
1/27/67	Apollo 1 fire – Death of Grissom, White, & Chaffee	Cape Canaveral, LC-34	Saturn 1B
7/20/69	Apollo 11 - First Lunar Landing Man on the moon	KSC-39A	Saturn V
4/12/81	STS-1 - first launch of RLV	KSC-39	Space Shuttle
1/28/86	STS-51L - Challenger disaster	KSC-39B	Space Shuttle
1998	First two pieces of ISS placed in orbit	Russia / KSC-39	Proton / Shuttle / ISS
2000	First expedition to ISS	Eastern Range	Shuttle / ISS

2.2 COMMUNICATION

The following table (Table 2-1) timeline covers the period from introduction to obsolescence (in many cases) of various types of communications, including wired, wireless, and optical communications systems. In addition, other major historical events and technical milestones along the path of progress, such as data rates of commercial modems, are included as well.

As can be seen scanning through this timeline, the introduction of disruptive communications technology often causes serious turmoil relative to established technology. Yet, in many cases (such as for the 19th Century French optical telegraph based on semaphores mounted on large wooden structures), there are actually periods of multiple decades during which an old technology may co-exist alongside the new, for various reasons.

For instance, the optical telegraph existed for sixty-one years as the primary method of quickly transmitting brief messages across France and Africa, and co-existed for many years with the more modern electric telegraph, due largely to the fact that the optical telegraph was more secure than the wired electric telegraph – the optical telegraph had no wires that could be cut between stations along the network!

On the other hand, there are also instances in which an institution goes out of business within just days of the arrival of a replacing technology, such as for the demise of the Pony Express when the electric telegraph finally spanned the North American continent with the final ‘electrical golden spike’ connection at Salt Lake City, UT. A similar transition is associated with the purchase of Alaska, purchased largely by the insistence of the upper management of Western Union to construct a telegraph line between America and Europe by way of Alaska and Asia. The plans for this telegraph line evaporated almost immediately after the successful invention and installation of higher performance submarine cable that could survive the depths of the Atlantic. In the case of Alaska, though, the mineral wealth and physical beauty are remembered long after the original reason has been relegated to the pages of history.

Historical timelines are valuable to broaden one’s thought process regarding linear time events. They illustrate that progress is never strictly linear, despite the use of timelines, and there are often evolutionary dead-ends along the path of progress, as well as disruptive technology periods, that completely change the time rate of change of progress.

Table 2-2 Communications Timeline (Wired, Wireless, Optical; Data Rates)

Date	Events
5/1794	French engineer Claude Chappe, creates a free space optical telegraph and coins the French word “télégraphe” which becomes telegraph in English. His system uses a series of semaphores mounted on towers manned by human operators to relay messages from tower to tower. The network grew to 556 stations spanning 3,000 miles across France, Algeria, and Morocco. A mobile network was built, and used during the Crimean War. Data throughput transfer rate was about 20 to 30 seconds per symbol.
1836-1837	Samuel Finley Breese Morse invents the single-wire electric Telegraph.
1/24/1838	Samuel F. B. Morse demonstrates his Telegraph over a 10-mile circuit at New York Univ. Data Rate: 10 WPM.
5/1/1844	First test of 35 km Telegraph line by Morse between Annapolis Junction, MD and Washington, DC.
1849	First teleprinter circuit (New York to Philadelphia) with printed letters instead of Morse symbols.
8/17/1858	First Trans-Atlantic (US - Europe) telegraph cable becomes operational between Trinity Bay, Newfoundland and Valentia, Ireland. It was dubbed the “Eighth Wonder of the World.” First test signals were sent on August 5, 1858. Queen Victoria and President Buchanan exchanged messages on August 16, 1858.
4/3/1860	Pony Express was inaugurated to deliver mail in only 10 days from St. Joseph, MO to Sacramento, CA.
10/21/1861	Western Union connects East Coast telegraph lines with West Coast lines at Salt City, UT
10/24/1861	Disruptive technology supersedes the Pony Express. Pony Express goes bankrupt, ruining investors.
3/27/1867	United States signs treaty to buy Alaska from Russia on urging from Western Union to acquire the land needed for a telegraph cable to Europe. “Seward’s Day”
2/14/1876	Patents filed for Telephone by both Alexander Graham Bell and Elisha Gray.
10/21/1879	Thomas A. Edison invents light bulb with the thought of providing an optical telegraph without wired lines.
1880	Alexander Graham Bell patents a free space optical telephone system, which he called the Photophone. The experimental Photophone was donated to the Smithsonian Institution, where it literally languished on the shelf for over half a century before light was once again used to transmit voice
1888	Heinrich Hertz discovers Radio Waves.
5/10/1894	Guglielmo Marconi sends a radio wave for 3/4 mile, inventing Wireless communication.
12/23/1900	Reginald Aubrey Fessenden invents Wireless Telephony (Radio), transmitting voice for the first time.
12/12/1901	First Trans-Atlantic Wireless communication.
Date	Events

1/18/1903	Marconi demonstrates first Trans-Atlantic two-way Wireless communication.
12/24/1906	Fessenden broadcasts voice and music over radio for the first time, surprising radio operators aboard ships at sea.
1921	First one-way wireless voice paging receiving equipment installed in police cars. (Detroit, MI. Callsign: KOP)
1924	First Mobile two-way Telephone System (New York City Police Cars)
1958	Schawlow and Townes at Bell Telephone Laboratories file for a patent on the laser
1960	Theodore Maiman builds the first working laser at Hughes Aircraft Company.
1960	300 Baud commercial modem speeds first achieved.
12/1968	ARPANet contract given to Bolt, Beranek & Newman (BBN) in Cambridge, MA. The output will become, in time, the Internet.
7/1970	Alohanet, first packet radio network, operation at University of Hawaii. Pioneering ideas contained in this network will form the basis of Ethernet.
9/1970	Low-loss fiber optic cable manufacturing techniques announced by Robert Maurer, Donald Keck and Peter Schultz of Corning Glass Works. They achieve a loss-limit of 20 dB/km, or less for optical fiber.
1972	Ethernet is invented by Robert M. Metcalfe, David R. Boggs, Charles P. Thacker, and Butler W. Lampson to interconnect the Xerox Alto, a personal workstation, with other Altos, and to servers and shared printers
1983	Cell phones commence nationwide operation in the United States
1984	William Gibson's novel, <i>Neuromancer</i> , provides the first vision of a globally interconnected network of computers. Gibson coins the word "cyberspace".
1987	56 kb/s commercial modem speeds first achieved.
2/1997	10 Mb/s Cable Modem commercial modem speeds first achieved.
6/1997	8 Mb/s ADSL commercial modem speeds first achieved.
8/1999	The Wireless Ethernet Compatibility Alliance (WECA) is formed with just six member companies to certify interoperability of Wi-Fi (IEEE 802.11) products and to promote Wi-Fi as the global wireless LAN standard across all market segments.
5/10/2000	FCC issues an NPRM (Notice of Proposed Rulemaking) to solicit comments on permitting Part 15 Ultra Wideband (UWB) transmissions.
5/2/2001	Technology research firm Webnoize reports the number of songs swapped on Napster was down 36 percent between March and April 2001. It is estimated that nearly 1.6 billion MP3 files changed hands in March. Average song length is approximately 4 MB. Internet traffic starts to decline simultaneously, precipitating an increase in order cancellations for telecom equipment from system providers.
11/30/2001	European Space Agency (ESA) Artemis satellite launched 12 July 2001 from the European launch base in Kourou, French Guiana on an Ariane 5 launch uses laser-based Silex Communication system to transmit 50 Mb/s to a SPOT 4 satellite in the first-ever publicly announced satellite-to-satellite laser-communication link demo.
2/14/2002	FCC adopts a First Report and Order (FCC 02-48) permitting Part 15 Ultra Wideband (UWB) transmissions under limited circumstances.

3.0 LAUNCH CENTERS AND RANGES (SUMMARY)

In order to evaluate future Range architecture needs, it is first necessary to understand the present Ranges and how their architectures evolved to today’s configuration. This section summarized most of the launch facilities within the U.S. and its protected territories. Detailed descriptions of each range are included in Appendix B. These descriptions provide the following type data (where available):

- Background
 - General
 - History
- Facilities
 - Major
 - Launch
- Instrumentation

There are numerous launch centers and missile ranges within the US and its protected territories. These centers and ranges launch various size rockets and missiles ranging from the small sounding rockets (Figure 3-1), all the way up to today’s Space Shuttles (Figure 3-2), Titan IV’s (Figure 3-3), and yesterdays Saturn V’s (Figure 3-4).

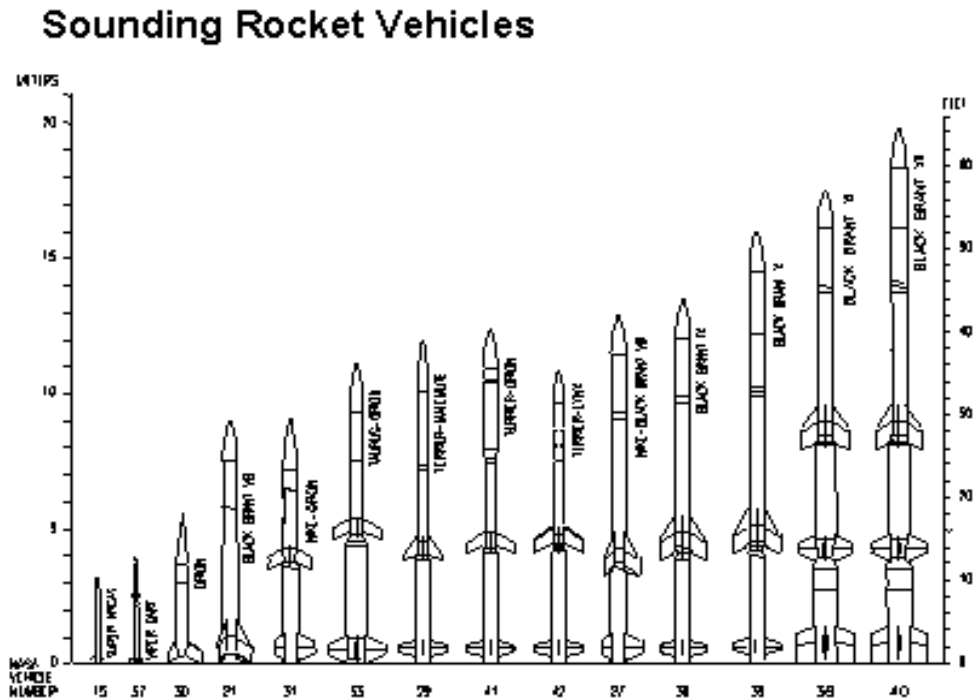


Figure 3-1 Sounding Rockets



Figure 3-2 Space Shuttle Launch



Figure 3-3 Titan IV-B

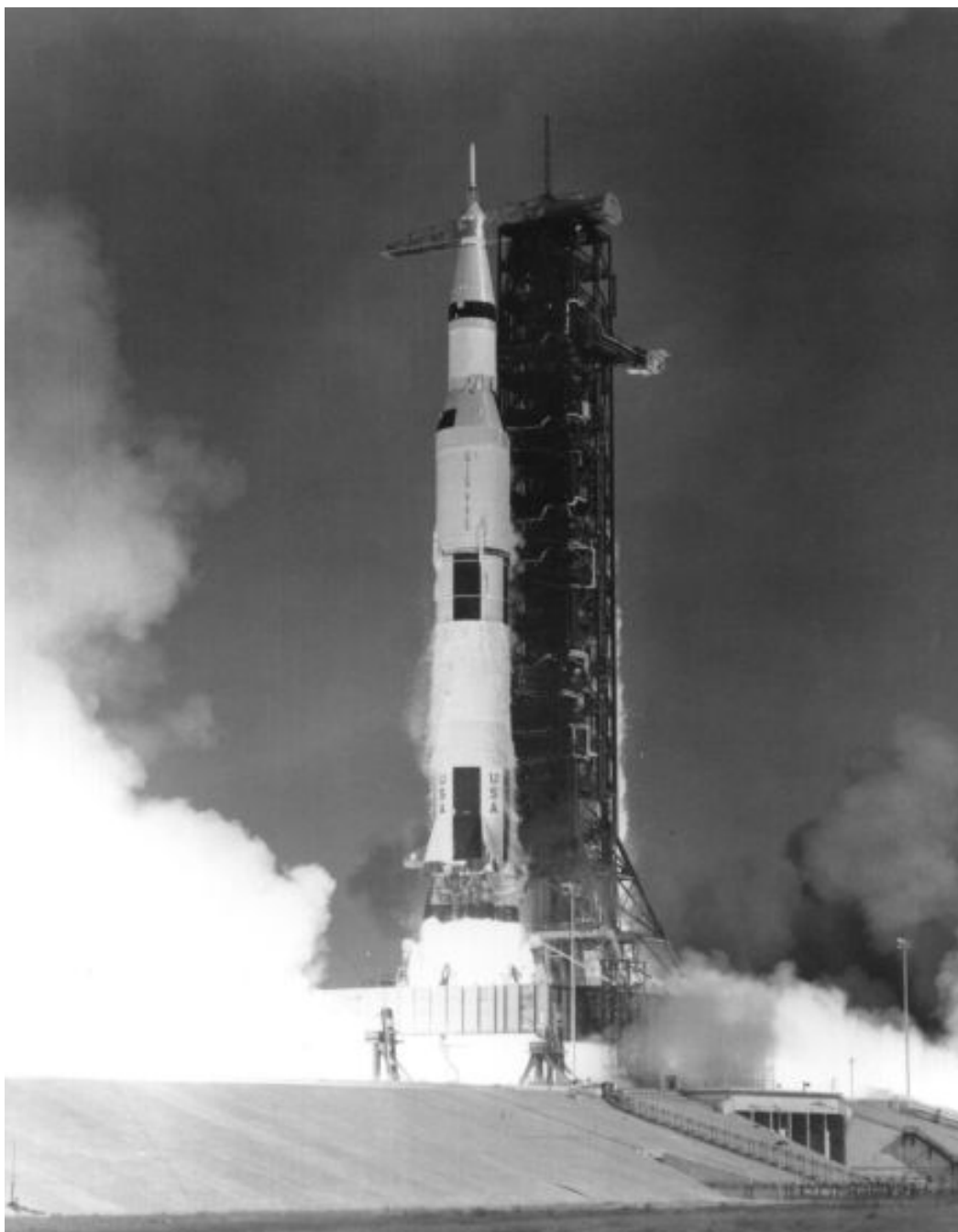


Figure 3-4 Saturn V Launch

Launch Centers and Ranges are often categorized with respect to whether the rocket or payloads launched are Suborbital or Orbital. Most orbital ranges also support suborbital launches.

A partial summary of US Launch Centers and Ranges discussed in this document is provided in Table 3-1. Detailed Range descriptions are included in Appendix B.

Table 3-1 Types of Launches At US Launch Centers & Ranges

Sect	Range & Launch Centers	Loc	Oper	Orbital			Suborbital					
				Gnd Launch	Air Launch	Sea Launch	ICBM	SLBM	NMD	Air Launch	Sndng	Others
3.1	Eastern Range	Florida	USAF	X	X		X	X		X	X	
3.2	Kennedy Space Center	Florida	NASA	X								
3.3	Western Range	California	USAF	X	X		X		X	X		
3.4	Wallops	Virginia	NASA	X	X					X	X	
3.5	Reagan Test	Kwajalein	US Army		X					X		X
3.6	Kodiak	Alaska	State	X						X		X
3.7	White Sands	New Mexico	USAF								X	X
3.8	Pt Mugu	California	USN					X			x	X
3.9	Sea Launch	Pacific Ocean	Boeing			X						
3.10	Poker Flats	Alaska	U of AK								X	
3.11	PMRF	Hawaii	USN						X	X		X
3.12	Eglin	Florida	USAF						X	X	X	X
3.13	China Lake	California	USN							X		X
3.14	Holloman	New Mexico	USAF						X	X		X

The above Launch Centers and Ranges contribute significantly to the U.S. space program. The primary U.S. launch locations are the Eastern Range, Kennedy Space Center, and the Western Range (Figure 3-5) for large missiles and Wallops Island for smaller missiles.

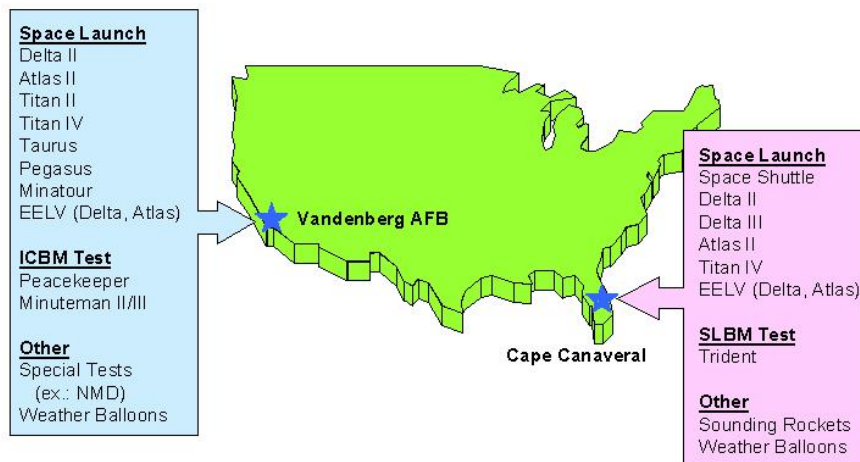


Figure 3-5 Eastern & Western Ranges

3.1 EASTERN RANGE

3.1.1 Background

The most active Launch Center and Range in the U.S. for large missiles is the Eastern Range (ER), headquartered at Patrick Air Force Base (PAFB), Florida. The Eastern Range is used for eastwardly launches in support of the following types of military, government and civilian missions:

- Manned missions
- Orbital
- Suborbital
- Inter-planetary
- Submarine Launched Ballistic Missiles

The Eastern Range was created in 1949 and is presently operated by the 45th Space Wing.

The area covered by the Eastern Range spans more than 5000 miles downrange (southeast) to Ascension Island in the south Atlantic. The Range also includes a northeast segment that runs to Argentia, Newfoundland. Launches are from Cape Canaveral Air Station (CCAS) on the Atlantic Coast of Florida at approximately 28.5N, 80.6W. Advantages of launching from the Cape are:

- Proximity to the equator to launch vehicles in Geosynchronous Earth Orbit (GEO)
- Over-water flight trajectories that make long-range missile flights possible over an area relatively free of shipping lanes and inhabited landmasses.

The Eastern Range is comprised of multiple operational locations. These are shown in Figure 3-6. This figure does not show Argentia, which is located off the picture to the north. Major Eastern Range facilities are located at the following:

- Patrick AFB
- Cape Canaveral Air Station (CCAS)
- Jonathan Dickinson Missile Testing Annex (JDMTA)
- Antigua, West Indies
- Ascension, South Atlantic
- Argentia, Newfoundland

NASA's Kennedy Space Center (KSC) is a separate entity from the Eastern Range and will be discussed in the next section.

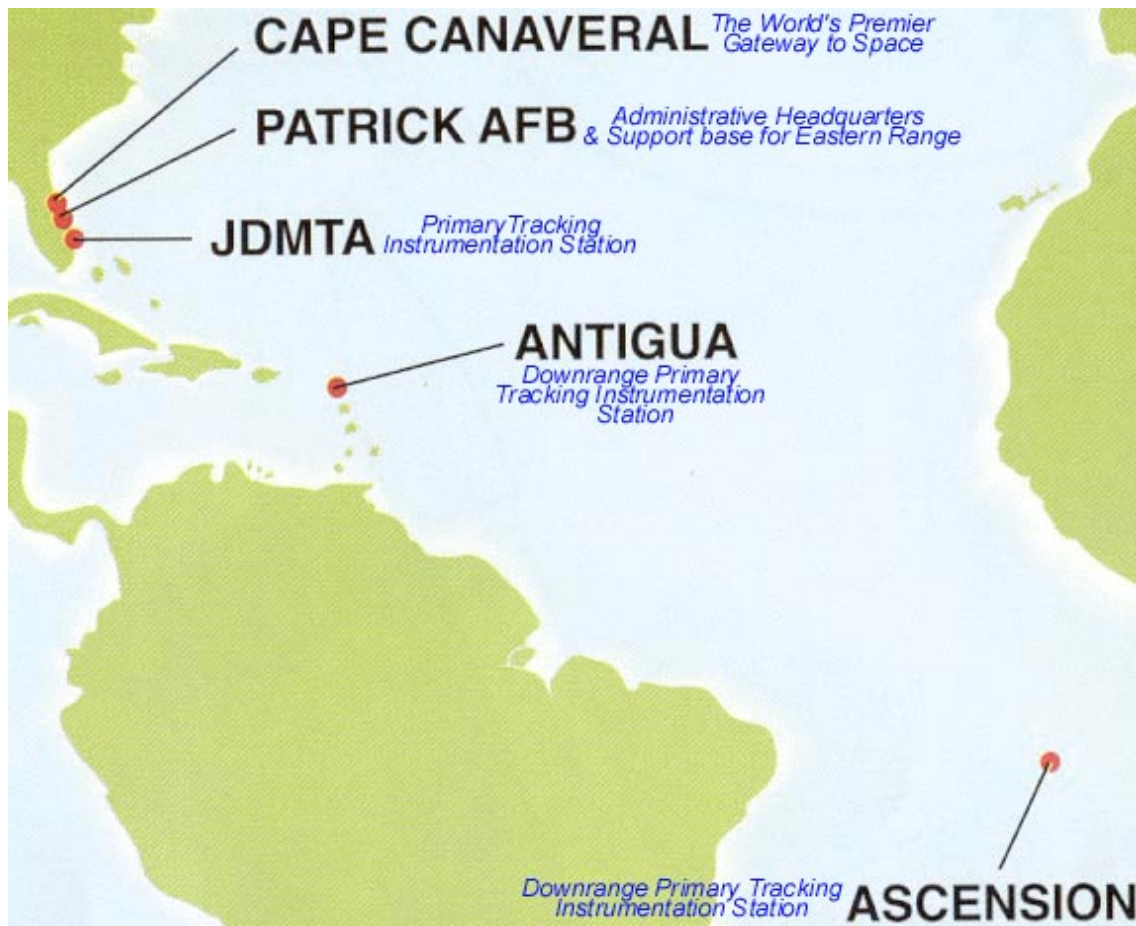


Figure 3-6 Locations of Eastern Range Facilities

In the past, the Eastern Range utilized significantly more facilities to carry out its mission. In addition to today's single south Florida site and two island sites, there were 14 other south Florida, Brazil, South Africa and Caribbean island tracking sites. These were supplemented with up to 23 tracking ships. At one time the Eastern Range extended beyond South Africa into the Indian Ocean.

Today, due to changing missions, range modernization, and NASA's TDRSS satellites, most of the downrange sites have been closed. The only downrange sites remaining are at JDMTA, Antigua and Ascension.

3.1.2 Facilities

General

The Eastern Range has the following major facilities:

Patrick AFB	Headquarters, Radar, Optics, Test Beds
CCAS	Launch Complexes (LC), Radar, Optics, Command Destruct, Control, Weather
KSC	Telemetry, Optics
JDMTA	Radar, Telemetry, Command Destruct
Antigua	Radar, Telemetry, Command Destruct
Ascension	Radar, Telemetry
Argentina	Radar, Telemetry, Command Destruct

In addition, facilities at NASA's Wallops Island and the Air Force Satellite Control Network's (AFSCN) site in New Hampshire may also be used for northern trajectories.

Launch

Cape Canaveral, with adjacent KSC, has approximately 50 launch complexes (Figure 3-7) numbered LC-1 through LC-47. Many of these are no longer in use. A select few are listed as National Historic sites. Some of the complexes contain multiple pads (i.e. 39A and 39B).



Figure 3-7 Cape Canaveral Launch Complexes (1960s & 1990)

3.1.3 Instrumentation

The Eastern Range has the following types of instrumentation:

- Radars (all)
- Telemetry (all)
- Optics (CCAS, PAFB)
- Command Destruct (CCAS, JDMTA, Antigua)
- Communication (all)
- Weather (CCAS, PAFB)
- Timing (all)

Radar

To enable precision tracking and range safety throughout the 5000-mile range, the Eastern Range has an assortment of launch head and downrange radars. The following radars are used on the Eastern Range:

<u>Site</u>	<u>Designation</u>	<u>Type</u>	<u>Band</u>	<u>Dia-ft</u>	<u>Comments</u>
PAFB	0.14	MIPIR	C	29	
CCAS	1.16	AN/FPS-16	C	12	
CCAS	1.39	MOTR	C	12	
CCAS	1.8		X	NA	Sea surveillance
KSC	19.14	MIPIR	C	29	
KSC	19.17	MCBR	C	12	
JDMTA	28.14	MIPIR	C	29	
Antigua	91.14	MIPIR	C	29	
Ascension	12.15	TTR	C	40	
Ascension	12.18	AN/FPQ-18	C	29	
Argentina	53.17	MCBR	C	12	

Ongoing modernization of the ER is intended to eliminate the need for most of these radars. As currently planned, the modernized ranges will use differential GPS tracking systems supplemented by seven radars at the ER. Three of the seven radars at the ER will be necessary only to support launches of the space shuttle, and three others will be located at downrange facilities to support ballistic missile tests and space object identification¹³.

¹³http://www.nap.edu/html/streamlining_range/ch4.html

Telemetry

A summary of Eastern Range Telemetry is as follows:

<u>Site</u>	<u>Telemetry</u>	<u>Dia.-Ft.</u>	<u>Comments</u>
KSC	TAA-3C	30	
KSC	TAA-24A	24	
JDMTA	TAA-50	50	4 systems
Antigua	TAA-8	80	
Antigua	TAA-3C	33	
Ascension	TAA-3C-1	33	Enclosed
Ascension	TAA-3C-2	33	Open
Ascension	Four Foot	4	Fixed antenna
Ascension	Shaped Beam	2.3 x 3	Fixed elliptic antenna

Optics

The Eastern Range has an assortment of fixed (Table 3-2) and mobile (3-3) metric optical systems near the launch head.

Table 3-2 Eastern Range Fixed Optical Sites

Site Designator	Instrument	Site Location	Lens Focal Length (inches)	Comments
Playalinda Bch	DOAMS	KSC	100 to 400	Canaveral National Seashore
CB DOAM	DOAMS	Cocoa Bch	100 to 400	Behind Ron Jon's Surf Shop
PIGOR	IGOR	PAFB	90 to 500	On A1A
MB ROTI	ROTI	Melbourne Bch	100 to 500	On A1A

Table 3-3 Eastern Range Mobile Optical Equipment

System	Metric	Lens Focal Length (inches)	Comments
ATOTS	Y	180 to 500	Advanced Transportable Optical Tracking System
Cinetheodolites	Y	60 to 120	
MIGOR	Y	90 to 500	Mobile Intercept Ground Optical Recorder
IFLOT	N		Intermediate Focal Length Optical Tracker
MOTS	N		Mobile Optical Tracking System
KTM	N		Kineto Tracking Mount

Command Destruct

Command Destruct capabilities are provide at the following sites:

- Cape Canaveral Air Station (CCAS)
- JDMTA
- Antigua
- Argentia

Wallops Island also provides support for some ER missions. Each Command site has redundant but totally separate systems. The redundancy originates at the power source and continues through the transmitters and other components all the way up to the antennas.

Communication

The Eastern Range has an extensive communication network consisting of the following:

- Communication Satellites
- Microwave links
- High Frequency (HF) radio
- Landlines (copper & fiber)
- VHF/UHF

Weather

Eastern Range Weather systems are at the following locations:

- CCAS
- Ascension

Timing

The ER Timing and Sequencing system has major equipment at the following locations:

- CCAS
- KSC
- JDMTA
- Antigua
- Ascension
- Argentia

3.2 KENNEDY SPACE CENTER

3.2.1 Background

NASA's John F. Kennedy Space Center (KSC) is the premier spaceport of the U.S. and, in many respects, of the world. It holds the following distinctions:

- Only U.S. manned Spaceport
- One of only 2 manned Spaceports in the world
- Only world spaceport to launch men to the moon

KSC is located on Merritt Island directly across the Banana River from the Cape Canaveral Air Station (CCAS) (Figure 3-8). It is a separate entity from the CCAS and the Eastern Range and contains its own launch facilities (LC 39A & LC 39B) and Launch Control Center (LCC). NASA and the Air Force share some facilities, operations and responsibilities at the two sites. Eastern Range assets are used for all launches.

KSC is located on the east coast of Florida approximately midway between Jacksonville and Miami, about 50 miles east of Orlando. KSC also shares its property with the Merritt Island National Wildlife Refuge and the Canaveral National Seashore. KSC covers more than 140,000 acres, making it about one-fifth the size of Rhode Island. Only about 6,000 acres are used for Space Center operations, the remaining is a wildlife sanctuary¹⁴.

KSC's primary mission is processing and launching the Space Shuttles (Figure 3-9). The Space Shuttles and their rollout dates are summarized below¹⁵:

<u>Name</u>	<u>Designation</u>	<u>Delivered</u>
Enterprise	OV-101	1975
Columbia	OV-102	1979
Challenger	OV-99	1982
Discovery	OV-103	1983
Atlantis	OV-104	1985
Endeavour	OV-105	1991

The Space Shuttles launch from LC 39A or LC 39B and, weather permitting, return for landing at the Shuttle Landing Facility (Figure 3-10). Alternate landing sites are Edwards AFB, California and White Sands, New Mexico. In case of a problem during launch, the shuttle may land back at KSC or select one of the Transoceanic Abort Landing (TAL) sites. The designated TAL sites are Ben Guerir Air Base, Morocco; Zaragoza Air Base, Spain, and Moron Air Base, Spain¹⁶. Appendix D has additional information on Shuttle landing sites.

¹⁴ http://www.kennedyspacecenter.com/html/ksc_map.html

¹⁵ http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/sts_overview.html#sts_program

¹⁶ <http://www-pao.ksc.nasa.gov/nasafact/tal.htm>



Figure 3-8 Kennedy Space Center and Cape Canaveral



Figure 3-9 Space Shuttle Launch



Figure 3-10 Shuttle Landing Facility (SLF)

3.2.2 Facilities

To complete its primary missions of recovery, preparation and launching the Shuttle, KSC has the following special facilities:

- Crawler-Transporter (Figures 3-11 & 3-12)
- HPF - Hypergolic Processing Facilities
- LCC – Launch Control Center (Figure 3-13)
- MILA – Merritt Island Launch Annex
- MLP – Mobile Launch Platform (Figures 3-11 & 3-12)
- OPF – Orbiter Processing Facilities
- Recovery Ships
- SLF – Shuttle Landing Facility (Figure 3-10)
- SSPF – Space Station Processing Facility
- VAB – Vehicle Assembly Building (Figure 3-13)
- Launch Facilities –LC-39A & 39B (Figure 3-11 & 3-12)

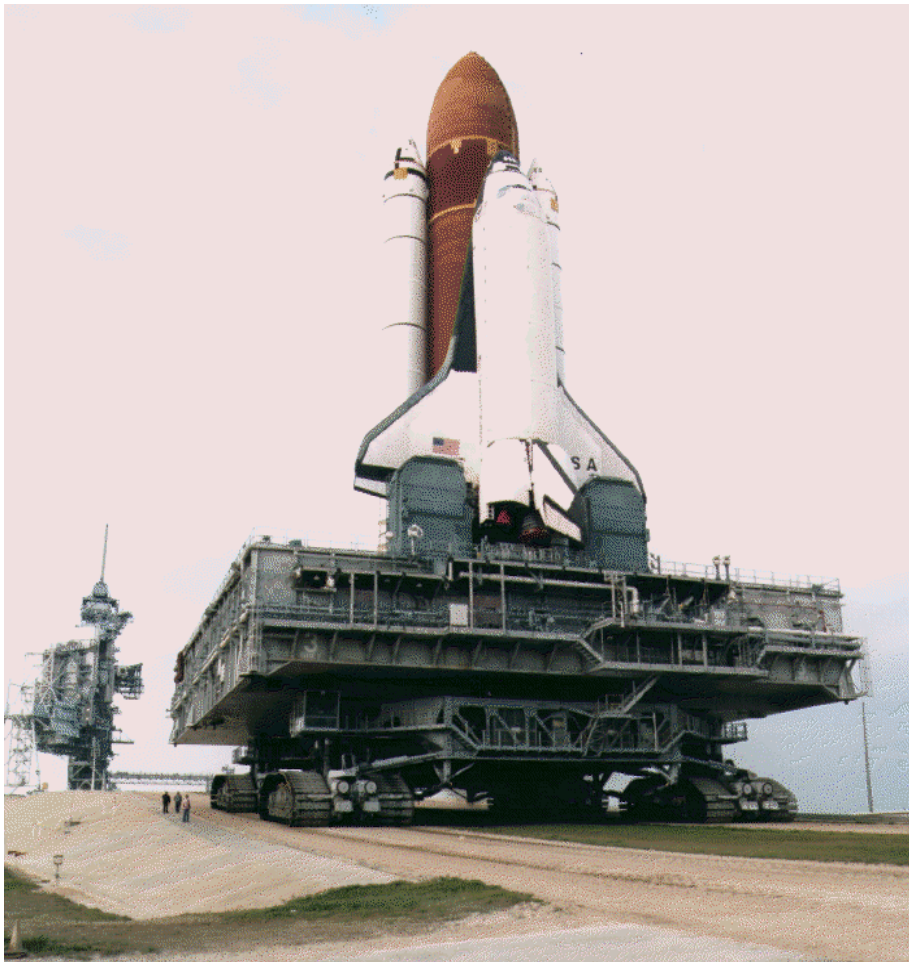


Figure 3-11 Crawler-Transporter With MLP & Shuttle At Pad

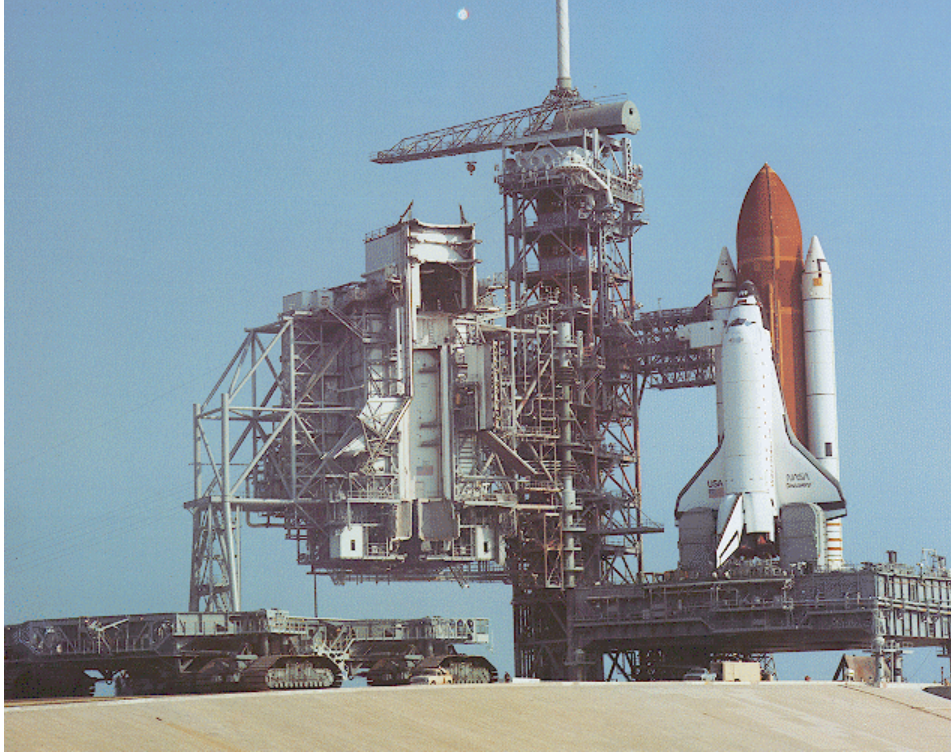


Figure 3-12 MLP with Shuttle At Pad; Crawler Leaving



Figure 3-13 VAB With LCC To Right

3.2.3 **Instrumentation**

KSC has the following types of Range instrumentation:

- Radar
- Telemetry
- Optics
- Command Destruct
- Communication
- Weather
- Timing

3.3 WESTERN RANGE

3.3.1 Background

Located on the Pacific Coast about 150 miles north of Los Angeles, Vandenberg AFB is the headquarters for the Western Range (Figure 3-14)¹⁷ and the 30th Space Wing. It primarily launches unmanned government and commercial satellites into polar orbits. Vandenberg also tests intercontinental ballistic missiles by launching them into the Pacific Ocean, with splashdown usually occurring at the Kwajalein Atoll (Reagan Test Site) within the Marshall Islands.

The Western Range presently has major land-based facilities at the following locations¹⁸:

- Anderson Peak (Monterey County, Ca)
- Pillar Point AFS (San Mateo County, Ca)
- Santa Ynez Peak (Santa Barbara County),
- Vandenberg AFB

The Western Range often uses fixed and mobile resources from other ranges to carryout its missions. These include:

- The Pacific Missile Range Facility 19 (PMRF) in Hawaii
- Reagan Test Site - Kwajalein, Marshall Island²⁰ (Army)
- Point Mugu (Navy)
- Laguna Peak (Navy)
- San Nicholas Island (Navy)
- White Sands Missile Range (Army)
- China Lake (Navy)
- Navy NP3D based at Point Mugu
- Air Force ARIA (Advanced Range Instrumentation Aircraft) at Edwards

Vandenberg grew out of Camp Cooke that was built in 1941 from a large ranch. The Vandenberg area is ideally oriented for missile launches. The northern portion has a coastline facing west and the southern portion has significant coastline facing south. This unique geography permits launch azimuths ranging from 154 to 280 degrees, enabling over-ocean ballistic and polar space launches. Vandenberg is the only location in the continental United States permitting polar orbit spacecraft launches without over-flying any land mass.

¹⁷ http://www.vandenberg.af.mil/30sw/history/tanks_to_missiles/lineage/history_and_lineage.html

¹⁸ <http://www.acq.osd.mil/te/mrtfb/commercial/sw30/wspace.html>

¹⁹ <http://www.acq.osd.mil/te/pubfac/pmrf.html>

²⁰ <http://www.smdc.army.mil/kmr.html>

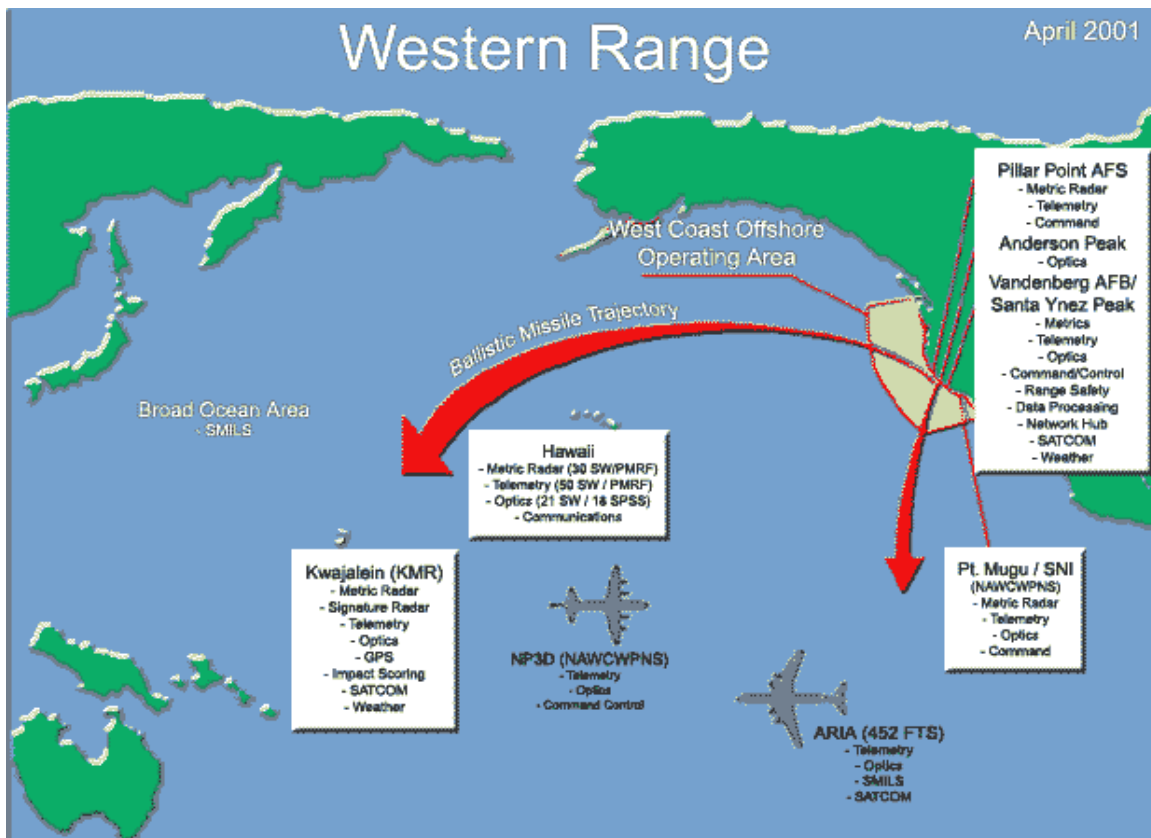


Figure 3-14 Western Range

3.3.2 Facilities

Vandenberg provides the buildings, facilities and equipment essential for missile and spacecraft operations. Launch complexes include the following:

- **SLC-2W** – Delta-II
- **SLC-3E** – Atlas-II AS
- **SLC-4W** –Titan II
- **SLC-4E** –Titan IV
- **SLC-6** – Delta IV (Shuttle)
- **Silo** – Minuteman III & Peacekeeper

SLC-6 (Figure 3-15) was initially built for the Manned Orbiting Laboratory (MOL). After MOL was cancelled in 1969, SLC-6 was abandoned for nearly a decade. In 1979, SLC-6 was reactivated and underwent an estimated \$4 billion modification program in preparation for use by the Space Shuttle program. Following the Challenger accident in

1986 and after a joint decision by the Air Force and NASA, SLC-6 was again abandoned. Today, SLC-6 has been modified for use with the Delta IV.²¹



Figure 3-15 SLC-6 In 1986

3.3.3 Instrumentation

Western Range key instrumentation is located at the following sites:

- Anderson Peak (Monterey County, CA)
- Pillar Point AFS (San Mateo County, CA) (Figure 3-16)
- Santa Ynez Peak (Santa Barbara County, CA)
- Vandenberg AFB

Additional instrumentation capability is provided by the Navy at Point Mugu, the Pacific Missile Range Facility, and by the Army at Reagan Test Site (Kwajalein) to support missions.

²¹ http://www.vandenberg.af.mil/30sw/history/tanks_to_missiles/launch%20programs/index.htm



Figure 3-16 Pillar Point Instrumentation Site

Range instrumentation includes the following:

- Radar
- Telemetry
- Command
- Optic
- Communications
- Weather

3.4 WALLOPS ISLAND

3.4.1 Background

Wallops Flight Facility is NASA's primary facility for sub-orbital programs.²² It also supports a limited number of orbital launches. Since it was established in 1945, Wallops Flight Facility has launched over 14,000 rockets as part of its research programs.

Wallops Flight Facility has been heavily involved in the manned space program and supports northbound launches on the Eastern Range. Wallops Flight Facility has also supported Project Mercury, Project Apollo, Project Gemini and Space Shuttle missions.

3.4.2 Facilities

Wallops Flight Facility is located on the Atlantic coast of northeastern Virginia. It is accessible from Maryland and from Virginia via Newport News. Wallops Flight Facility is dispersed over three different land areas, as shown in Figure 3-17.

Today, Wallops Flight Facility includes the following primary facilities:

- launch pads
- Tracking and Data Acquisition
- Assembly facilities
- Blockhouses
- Hazardous Storage
- Range Control Center
- Virginia Commercial Space Flight Authority
- Research Airport

²² http://www.wff.nasa.gov/pages/wallops_history.html

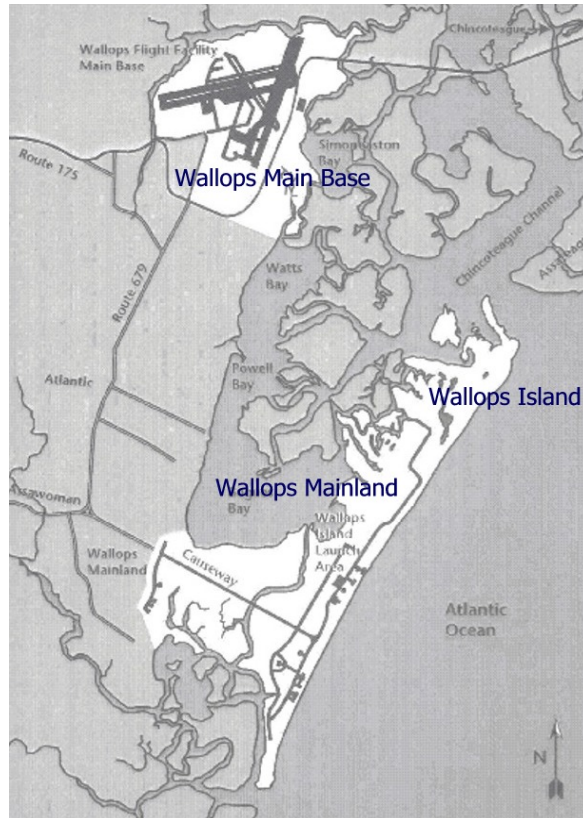


Figure 3-17 Wallops Flight Facility Three Main Sites



Figure 3-18 Wallops Island Launch Facilities

3.4.3 Instrumentation

Wallops Flight Facility instrumentation includes the following²³:

- Telemetry
- Radar
- UHF transmitters & Range Safety systems
- Film/video tracking
- Communications
- Weather

Wallops Flight Facility radars often provide support for the Eastern Range during launches with northern trajectories.

In addition, Wallops Flight Facility has mobile launch facilities that are offered as a service to other ranges. It has provided support at Argentia for the Eastern Range and at Cordova, AK for the Kodiak launch facility.

3.5 OTHER RANGES

There are numerous other Government ranges and test facilities in the U.S. that do not specifically support missile launches. Most major facilities are members of the Major Range and Test Facility Base (MRTFB). The MRTFB is a set of service activities, which are regarded as "national assets." These assets are sized, operated, and maintained primarily for Department of Defense (DoD) test and evaluation missions. However, the MRTFB facilities and ranges are also available to commercial and other users on a reimbursable basis²⁴.

A list of MRTFB Ranges and Test Facilities includes the following:

- **Department of the Army**
 - Aberdeen Test Center, Aberdeen, MD
 - Dugway Proving Ground, Dugway, UT
 - High Energy Laser Systems Test Facility, WSMR, NM
 - **Reagan Test Site, Kwajalein Atoll**
 - **White Sands Missile Range, White Sands, NM (includes Electronic Proving Ground, Fort Huachuca, AZ)**
 - Yuma Proving Ground, Yuma, AZ (includes Cold Regions Test Center, AK, and Tropic Regions Test Center, AZ/HI/PR)

²³ http://www.wff.nasa.gov/vtour/pages/wff_vt_p23x.htm

²⁴ <http://www.dote.osd.mil/tr/mrtfb.html>

- **Department of the Navy**
 - Atlantic Undersea Test and Evaluation Center, West Palm Beach, FL / Andros Island, Bahamas
 - Naval Air Warfare Center, Aircraft Division, Patuxent River, MD
 - **Naval Air Warfare Center, Weapons Division, Point Mugu, CA**
 - **Naval Air Warfare Center, Weapons Division, China Lake, CA**
 - **Pacific Missile Range Facility, Kauai, HI**

- **Department of the Air Force**
 - **30th Space Wing, Vandenberg AFB, CA**
 - **45th Space Wing, Patrick AFB, FL**
 - **Air Force Air Armament Center 46th Test Wing, Eglin AFB, FL**
 - Air Force Flight Test Center, Edwards AFB, CA
 - Arnold Engineering Development Center, Tullahoma, TN
 - Nevada Test and Training Range, Nellis AFB, NV
 - Utah Test and Training Range, Hill AFB, UT

- **Department of Defense Agencies**
 - Joint Interoperability Test Command, Fort Huachuca, AZ

Bold name sites are discussed in Appendix B.

US and Foreign Ranges used by NASA since 1980 include the following²⁵:

- **Wallops Island, VA (USA)**
- **Poker Flat, AK (USA)**
- Ft. Yukon, AK
- Cape Perry, Canada
- Andoya, Norway
- Ny-Alesund, Spitzbergen (Norway)
- Esrange, Sweden
- Ft. Churchill, Canada
- Sondre Stromfjord, Greenland
- Punta Lobos Peru
- Alcantara, Brazil
- Tortuguero, Puerto Rico
- **Kwajalein Atoll, Marshall Islands**
- Kenya, Africa
- **White Sands, NM (USA)**
- Woomera, Australia

²⁵ <http://rscience.gsfc.nasa.gov/opsrang.html>

4.0 COMMUNICATION / DATA NETWORK TECHNOLOGIES

During the history of telecommunications, there have been relatively few major shifts in the high-tech landscape due to the introduction of disruptive technology. “Disruptive technology” is defined as technology that is not an evolutionary development built on previous technology; rather, “disruptive technology” is technology that results in a major shift in the way things will be done henceforth. Disruptive technology completely makes obsolete an earlier technology, or introduces a technological capability previously not possible. True disruptive technology must result in (at least) an order of magnitude reduction in cost, to overcome any pre-existing investments and any existing support infrastructure supporting an older technology competing in the same business space. Otherwise, a “disruptive” technology without a significant cost advantage merely becomes an alternative technology.²⁶

Clearly, the historical transition from vacuum tube technology to solid-state technology represents such a shift. In the 1950’s, and even until the late 1960’s, nearly every corner drugstore in the United States had a vacuum tube test set and an assortment of vacuum tubes on display in a rack for the do-it-yourself home-TV repairman. The ubiquitous vacuum tube test sets quickly started vanishing once solid-state TVs came on the market, and were completely gone by the mid-1970’s. Solid-state technology was a disruptive technology that overwhelmed vacuum tube technology.

Disruptive technology need not be a “replacement” technology. Consider the introduction of Ethernet. Prior to its invention in 1972, computers were not widely networked, even in Local Area Networks (LANs). Prior to the invention of Ethernet, an occasional computer would be networked with a physically co-located computer; but the thought of having a global computer network, interconnecting large numbers of computers, was still a topic that even science fiction had not speculated about in 1972; the first science fiction book on this topic to gather much public interest was published in 1984.²⁷

²⁶ An ‘order of magnitude’ is used in the precise mathematical sense here of being a factor of 10. A factor of five or even six is not usually sufficient to dislodge existing technology. At least a factor of 10, or more, is usually required for disruptive technology to displace pre-existing technology. Disruptive technology is also the key to changing the way things can be done, implementing new ways of accomplishing tasks, and by quickly creating the opportunity for new companies supporting significant private wealth creation. Old school, established companies typically do not recognize the advent of disruptive technology until they are overwhelmed by it in the marketplace.

²⁷ Gibson, William. **Neuromancer**. Ace Books, New York, 1984. This was the first science fiction book to explore the global information network (i.e., net, or matrix) culture of the near future. Gibson coined the term “cyberspace” and created a completely new cyberpunk genre of literature in this work, his debut novel. For more on Gibson, see: <http://www.antonraubenweiss.com/gibson/index.html> . Being largely unfamiliar with computers, Gibson did not extrapolate existing technology; instead, he envisioned an entirely new paradigm. Because of this, he largely ‘got it right’ relative to what actually transpired.

In terms of modulation techniques, disruptive technology shifts are very few. One possible example that might, without careful thought, be considered disruptive technology is the introduction of Frequency Modulation (FM) by Armstrong, relative to older, pre-existing Amplitude Modulation (AM) techniques. Though FM provides a major improvement in the reduction of atmospheric induced noise effects, AM transmissions continue to this day on the commercial AM Broadcast band.²⁸ FM was not a disruptive technology because it did not provide an order of magnitude cost reduction relative to older AM radio equipment. From this viewpoint, FM is merely an alternate (although improved) way of transmitting information, with technical advantages for niche applications.

The following discussions explore both an historical and a current survey of the extant and disruptive technologies required for achieving seamless information networks at Spaceports and Ranges. These discussions support the overarching vision of the total integration of existing and new technologies to provide a new and robust way of interconnecting the Range assets, Range operations, and Range users during the launch event. Implicit in this integration is the requirement for flexibility and the need for modularization by function, as well as by physical module, to ease the incorporation of newer technologies yet to be fielded, or even imagined.

The following views of key technologies establish and explore a technological foundation for implementing tightly-linked information networks that will enable a future Space Based Range (SBR) Distributed Subsystem to support the Spaceports and Ranges of tomorrow. These communication and data network technologies will be needed to provide the required infrastructure to enable routine access to space. Historical perspectives, in terms of failed technologies, are also discussed, to provide a reference for understanding the total landscape (such as for DSL) and for recognizing disruptive technology (DOCSIS). In addition, the disruptive technology of Ultra Wideband is identified and explored.

4.1 ETHERNET

Presently, Ethernet is the most commonly deployed protocol for connecting computers into a local area network (LAN). For the half-duplex versions, it is based on a Carrier Sense Multiple Access with Collision Detection (CSMA/CD) protocol, or on switching hubs for the full-duplex versions. The Institute of Electrical and Electronic Engineers (IEEE) governs all the standards for Ethernet. Ethernet was invented in late 1972 by Robert M. Metcalfe, David R. Boggs, Charles P. Thacker, and Butler W. Lampson to interconnect the Xerox Alto personal workstation with other Altos, and to servers and shared printers. The application for the patent for Ethernet was filed with the US patent

²⁸ Even the latest, widely fielded fiber optic transmission systems, transmitting at speeds of 10 Gb/s, for example, still use NRZ (None Return to Zero) modulation, which is simply Amplitude Modulation of a fixed optical carrier. Some 40 Gb/s systems are starting to use RZ (Return to Zero) modulation, for reasons of improving performance – RZ is still fundamentally Amplitude Modulation, however.

office in 1975, and the patent was granted to Xerox Corporation on December 13, 1977 (US Patent 4,063,220). Available now in data rates from 10 Mb/s through 10 Gb/s, and soon to include 40 Gb/s, and even higher data rates, Ethernet is by far the dominant LAN protocol technology in use today.

LANs are not the only place where Ethernet is being deployed. Extending Ethernet beyond LANs to WANs (Wide Area Networks) is also underway. Performance is one of the primary reasons that Ethernet is often considered in place of TCP/IP (Transmission Control Protocol/Internet Protocol) for longer physical runs, such as needed in a WAN.²⁹ The older WAN protocol technology of TCP/IP is prone to lose data, often haphazardly. Ethernet can eliminate jitter and increase efficiency in WANs through the provisioning of active flow control.³⁰ This is a significant advantage of using Ethernet protocols over SONET and ATM relative to using TCP/IP protocols over SONET and ATM. Ethernet also provides 99.999% (i.e., five-nines) uptime, as well as support for VLANs (Virtual Local Area Networks) that are switchable within sub-seconds of a link failure (to switch around hardware failures) by using 802.1w Rapid Spanning Tree Protocol (RSTP). In addition, it is possible to aggregate VLANs into groups by using the 802.1s protocol. Class of Service is defined in Ethernet by the 802.1p protocol. Multi-point to multi-point service is defined in Ethernet by the 802.1q protocol. Combining 802.1p and 802.1q, it becomes possible to provide high CoS (Class of Service) operation for voice or other traffic requiring low latency. Because of these many features and advantages over TCP/IP, as well as the wide range of speeds supported from 10 Mb/s through 10 Gb/s and higher, Ethernet is considered *the* next-generation WAN technology.³¹ Ethernet is thus the premiere protocol for implementing both LANs *and* future WANs. It also provides a path that can be used to simplify network infrastructures to a common technology among LANs, WANS, and other networks. Because of these characteristics and trends, Ethernet is the primary candidate protocol technology for providing a seamless fusion of communication between widely separated LAN and WAN users on Spaceports and Ranges of the future. The following sections describe Ethernet in all its various variations, and largely follow Ethernet history in the order of presentation.

²⁹ There is also an economic labor-cost benefit, as well, in introducing Ethernet into the WAN. As there have been relatively few WAN engineers historically in contrast to LAN engineers, extending Ethernet into the WAN takes advantage of an already trained, and relatively inexpensive, Ethernet labor force for network administration and network installation tasks. WAN engineers historically have been highly compensated physical layer engineers, largely unfamiliar with Ethernet protocols. Extending LAN technology into the WAN thus can reduce the labor costs associated with both installing and supporting future WANs, in addition to providing performance improvements.

³⁰ Musich, Paula. *Users clamor for 10-gig Ethernet*. eWeek, May 15, 2000, p. 20. Ziff-Davis Publishing.

³¹ Oliva, Val. *Ethernet, The Next Generation WAN Technology*. Version 1.0, May 2002. Foundry Networks. <http://www.10gea.org/SP0502NextGenerationWAN.pdf> Retrieved 3 June 2002.

4.1.1 10 Base T

The IEEE 802.3 Standard defines and governs half-duplex Ethernet CSMA/CD, which is further defined as part of the Media Access Control (MAC) sublayer of the Layer 2 Data Link layer of OSI (Open Systems Interconnection).³² IEEE 802.3 specifies how information is formatted for transmission as well as the method network devices use to gain access to, or control of, a network for transmission of data. At present, the majority of installed systems commonly support two versions of half-duplex Ethernet. These two versions of Ethernet are denoted as 10BaseT and 100BaseT, and are the two most common versions of Ethernet existing in legacy systems. Although the ten-times-faster 100BaseT version of Ethernet is better at handling the difficulties associated with peak traffic problems, both the 10BaseT and 100BaseT suffer from the same issues regarding data overload that occurs when too many users simultaneously try to use a LAN, or push too much data through a LAN. Specifically, for CAD or imaging application traffic, with a higher peak throughput, Fast Ethernet can address the data overload problem. But, if the problem is caused by an overload of users, neither 10BaseT nor 100BaseT works well above a 50-percent utilization rate due to collision detection overhead impacts.^{33, 34} (Fortunately, full-duplex versions of Ethernet can be used to reduce data congestion when trying to push LANs to higher throughputs.)

The most common form of legacy Ethernet is **10BaseT**, which denotes a peak transmission speed of **10 Mb/s** using copper **Twisted-pair** cable. 100BaseT, also called *Fast Ethernet*, is an upgraded standard (IEEE 802.3U) for connecting computers into a local area network (LAN). 100BaseT Ethernet works just like regular Ethernet except that it can transfer data at a peak rate of 100 Mb/s. It's also slightly more expensive and less common among legacy systems than its slower 10BaseT predecessor. In newer systems, however, 100BaseT/10BaseT auto-switchable hardware is commonly fielded.

Theoretically, cable runs up to 2500-meters are supported by 10BaseT, whereas 100BaseT is theoretically limited to 250-meters. Within the 250-meter distance, either can be used, often over the same cabling, such that an upgrade to 100 Mb/s 100BaseT Fast Ethernet hardware often can be implemented without replacing the cable plant installed within existing facilities.

³² OSI is divided into seven layers. They are defined as Layer 1, Physical, i.e., PHY; Layer 2, Data Link; Layer 3, Network; Layer 4, Transport; Layer 5, Session; Layer 6, Presentation, or Syntax; Layer 7, Application. Layer 2 is further divided into the MAC layer and the Logical Link Control (LLC) layer. Layer 2 encodes and decodes between bits and packets. The MAC sublayer of Layer 2 controls how a computer on the network gains access to the data and permission to transmit them, whereas the LLC layer controls frame synchronization, flow control and error checking. Layer 3 provides switching, routing, and packet sequencing. Layer 4 ensures complete data transfer. See: http://www.webopedia.com/quick_ref/OSI_Layers.html

³³ <http://www.ethermanage.com/ethernet/ethernet.html>

³⁴ <http://www.networkmagazine.com/article/NMG20000727S0014>

The concept of Fast Ethernet was first proposed in 1992. The Fast Ethernet Alliance (FEA), comprised of a group of vendors, was formed in 1993 to standardize the requirements for a faster Ethernet to achieve 100 Mb/s in place of 10 Mb/s data transfer rates. The basic business argument that was used to “sell” the concept of 100BaseT Fast Ethernet was that 100BaseT would be a legacy and infrastructure-supporting technology. Specifically, it would use the same transmission protocol as older versions of Ethernet and would be compatible with the same types of cable and connectors. Also, because 100BaseT would be a continuation of the old Ethernet standard, many of the same network analysis tools, procedures, and applications that ran over the old Ethernet network would work with 100BaseT. The end result would be that less capital investment would be required to convert an Ethernet-based network to Fast Ethernet than to other forms of high-speed networking, and vendors providing Ethernet could prevent any competing technologies from crowding their turf.

Fast Ethernet comes in three basic configurations. These three configurations, based on the type of cable used, are 100BaseTX, 100BaseT4, and 100BaseFX. Both 100BaseTX and 100BaseT4 are intended for use with older twisted-pair cabling standards, while 100BaseFX is meant for use over newer fiber optic cabling.

The 100BaseTX standard is compatible with cables having two pairs of Unshielded Twisted Pair (UTP) or Shielded Twisted Pair (STP) wiring. One pair supports reception and the other supports transmission. Currently, two basic cable standards meet this requirement: EIA/TIA-568 Category 5 UTP and IBM's Type 1 STP. For new installations, Category 5 cables are considerably more expensive than the older Category 3 cables, but provide enhanced range performance at the 100 Mb/s data transfer rates. 100BaseTX can provide full-duplex performance with network servers. In addition, it uses only two of the four pairs of wiring in the cable, leaving two pairs in reserve for future enhancements to installed networks.

The 100BaseT4 standard Fast Ethernet can use a less sophisticated, less-expensive cable than Category 5. The reason is that 100BaseT4 uses four pairs of wiring: one pair for transmission, one pair for reception, and two other pairs that can either transmit or receive data. Therefore, 100BaseT4 has the use of three pairs of wire to either transmit or receive data. By dividing up the 100Mbit/sec data signal among the three pairs of wires, 100BaseT4 reduces the signaling bandwidths carried on each pair of wires, and allows the successful use of lower-quality cabling. Cable types denoted as Categories 3 and 4 UTP cabling, as well as Category 5 UTP and Type 1 STP, all work well in 100BaseT4 implementations. Category 3 and 4 cabling were once the best cable available, and still exist in many legacy cable plants within buildings. Even if cable is not already installed, they cost less than Category 5 cabling for new installations at the expense of not providing any future upgrade paths. Because 100BaseT4 uses all four pairs of wiring, it cannot support full-duplex operation even though the generic 100BaseT standard does support full-duplex operation.

The 100BaseFX Fast Ethernet offers operation with MMF (multi-mode fiber optic cable, i.e., fiber having a 62.5-micron core and 125-micron cladding). MMF is considerably easier to work with than SMF (single-mode fiber, 7-9 micron core, and 125-micron cladding), and is much cheaper than SMF. The drawback is that faster OC-48 2.5 Gb/s operation is not possible over the legacy MMF, and short of replacing hardware; there are minimal upgrade paths from 100BaseFX to links with data transfer rates at, and above 1 Gb/s. The 100BaseFX standard often suffices for backbone use within a single building, connecting Fast Ethernet repeaters around the building and providing all the traditional benefits of fiber optic cabling such as protection from electromagnetic noise, increased security, while achieving reduced path losses relative to RF cables thereby permitting longer distances to exist between network devices.

4.1.2 Gigabit Ethernet (GbE) (1000BaseT/1000BaseX) and 10GbE

Newer Ethernet standards surpass the performance of Fast Ethernet and include Gigabit (1000 Mb/s) Ethernet (802.3z/802.3ab), and 10 Gigabit Ethernet (also known variously as 802.3ae, 10 GbE, and 10Gbase). There are two Gigabit Ethernet standards describing Ethernet systems that operate at 1000 Mb/s. The 802.3z standard describes the specifications for the 1000BaseX fiber optic Gigabit Ethernet system.³⁵ Present standards define and support operating distances of 100 meters and 300 meters over MMF (multi-mode fiber) at 850 nm with 1000BaseSX, as well as distances of 2, 10, and 40 km over SMF (single-mode fiber) at 1300 nm with 1000BaseLX. The other Gigabit Ethernet standard, 802.3ab, describes the specifications for the 1000BaseT twisted-pair Gigabit Ethernet system.³⁶ Both are mature standards, and as of June 2002³⁷, the price for Gigabit Ethernet Network cards has dropped below \$100. With the transition of Gigabit Ethernet hardware to commodity pricing of hardware conforming to a mature standard, the 1 Gigabit Ethernet Alliance that established these standards has even been disbanded. In its place, the 10 Gigabit Ethernet Alliance has been working the process of defining the interface standards for Ethernet data transmission at 10 Gb/s, to be governed by the IEEE 802.3ae standard.³⁸ Founded in February 2000, the 10 Gigabit Ethernet Alliance already had fifty-plus members as of May 2000.³⁹ As of December 2001, this group had resolved all the open issues with the standard, and the final ratification of this

³⁵ <http://grouper.ieee.org/groups/802/3/z/public/index.html>

³⁶ <http://grouper.ieee.org/groups/802/3/ab/public/index.html>

³⁷ Koppurapu, Chandra. *10 Gig to push Ethernet beyond the LAN*. Network World, June 24, 2002, <http://www.nwfusion.com/news/tech/2002/0624tech.html> Retrieved 1 July 2002.

³⁸ <http://www.10gea.org/index.htm>

³⁹ Musich, Paula. *Users clamor for 10-gig Ethernet*. eWeek, May 15, 2000, p. 20. Ziff-Davis Publishing.

10 Gb/s standard was expected in 2002. Final ratification of 802.3ae actually occurred on June 13, 2002.^{40,41}

The new 802.3ae standard of June 2002 establishes a framework for successfully expanding Ethernet from just the LAN into the MAN and WAN. Further, unlike Gigabit Ethernet, full duplex is the only mode supported; the era of simplex Ethernet links is no longer an issue. The 802.3ae standard also preserves and supports all older Ethernet definitions regarding minimum and maximum frame size and frame formatting. In a clear break with older Ethernet standards, 802.3ae is only defined for optical networks. This is because it has become technically impossible to continue to provide operation over copper twisted shielded pairs at increasing data rates; the days of similar but different Ethernet standards at each data rate, operating over both copper and optical fibers, are over. Both LAN and WAN physical interfaces are defined in 802.3ae. The three most important physical interfaces for the LAN include full-duplex serial interfaces categorized as:

- 10Gbase-SR, which details **Short Reach** operation at a wavelength of 850 nm using MMF (multi-mode fiber) at distances up to 990 feet
- 10Gbase-LR, which details **Long Reach** operation at a wavelength of 1310nm using SMF (single-mode fiber) at ranges up to a little more than 6 miles
- 10Gbase-ER, which details **Extended Reach** operation at a wavelength of 1550nm using SMF at ranges to more than 24 miles

A WAN PHY (Wide Area Network physical layer) definition is also contained in 802.3ae that defines physical interfaces operating at a serial data rate of 9953.28 Mb/s, providing full compatibility with OC-192 10 Gb/s SONET operation. The WAN PHY definition includes the same short, long, and extended reaches as for the LAN, but further allows transport of Ethernet data over Layer 1 SONET networks. Because of SONET compatibility, it is now possible for service providers to use already-installed add/drop multiplexers or repeaters to transport Ethernet over SONET. Likewise, the 802.3ae WAN PHY significantly reduces the cost of OC-192 hardware, as the jitter requirements to achieve acceptable Bit Error Rates (BERs) are reduced relative to first generation OC-192 SONET equipment and expensive stratum clocking is no longer required. Because of the lower costs, and reduced difficulty in fielding 802.3ae hardware relative to older OC-192 SONET gear, new 802.3ae equipment will largely eliminate the continued sale of first generation OC-192 SONET gear sold in large volumes in 2000-2001 by JDS Uniphase, Nortel, and other OEMs (Original Equipment Manufacturers). The disruptive technology of 10 GbE has largely captured the 10 Gb/s transponder market, at least for sales of new equipment to be fielded.⁴²

⁴⁰ <http://grouper.ieee.org/groups/802/3/ae/index.html>

⁴¹ 10-GigE Vendors Get Cold Feet, Light Reading, 19 June 2002, http://www.lightreading.com/document.asp?doc_id=17570, retrieved 20 June 2002.

⁴² Kopperapu, Chandra. *10 Gig to push Ethernet beyond the LAN*. Network World, June 24, 2002,

Despite final ratification of the specification, there have been relatively few sales of 10 GbE equipments. This is due to both the economic downturn in the marketplace, and the high cost (in 2002) of \$80,000 per port for 10 GbE. Over the 2002-2004 time span, equipments for 10 GbE will experience a slow ramp to full market acceptance. However, by 2005, as per port costs drop to \$7,800 for 10 GbE, the economic equation for 10 GbE will toggle to very favorable and significantly larger numbers of 10Gbase WAN PHY equipments will likely become fielded.⁴³

A favorable transition to 10 GbE will occur because of the economics for users needing high bandwidths of leasing bandwidth versus buying bandwidth. Currently (June 2002), the cost of leasing T1 lines (1.544 Mb/s) is priced around \$1,000/month to \$750/month.⁴⁴ Minimal further price erosion is likely, as this cost is close to the minimum that can provide a still-acceptable Return on Investment (ROI) for equipment suppliers at current low interest rates. If anything, these prices per month for T1 equipments will likely rise slightly over the next two or three years as interest rates edge slowly upwards.

The economic incentive to transition to 10 GbE will not occur until the onetime cost of purchasing 10 GbE equipment drops to approximately 10 times the per month cost of leasing T1 lines. It is only around this pricing breakpoint that the disruptive technology of 10 GbE, even if used wastefully in terms of bandwidth, becomes more than an order of magnitude cheaper than a single T1 set of equipment, even though 10 GbE provides over 6,400 times more data throughput! The issue is not data throughput, but is instead simply the equivalence of price with significantly more data throughput.

This results from the normal business practice of recovering the cost of leased equipment in 10 months by charging 1/10th of the total cost per month. For example, the price in mid-2002 of T1 equipment is around \$7,500, if it can be leased for around \$750/month. In this model, 10 GbE therefore will start to cross the economic price boundary necessary to become cost-effective with T1 equipment at a per port price of around \$7,500-\$7,800. With a rapid drop in price expected for 10 GbE equipment between 2002 and 2005, to drop the price to the \$7,800 range, the general acceptance for 10 GbE will no doubt ramp quickly starting in late 2003 to early 2004, with high volume acceptance for 10 GbE occurring by 2005 if not by mid to late 2004. The subsequent result will be the decline in the numbers of T1 equipments sold to businesses needing high data rates, simultaneous with the improvement in sales of 10 GbE equipment. Low-cost 10 GbE equipments available starting in 2005 will largely replace the demand for all new sales of T1

<http://www.nwfusion.com/news/tech/2002/0624tech.html> Retrieved 1 July 2002.

⁴³ http://www.lightreading.com/document.asp?doc_id=17570

⁴⁴ http://www.lightreading.com/document.asp?doc_id=17570

equipment, in addition to replacing the demand for older generation OC-192 SONET serial transmitters/receivers and transponders.

As stated previously, the migration of Ethernet technology from the LAN to the WAN, and to the physical layer of the WAN (i.e., the WAN PHY) is well underway, too. IEEE 802.3ae supports the WAN Sub-layer, which supports OC-192. Adding the WAN PHY, which is a “plug-in” to an existing OC-192 SONET interface, within 802.3ae has created an omnipresence for Ethernet within Layer 2. Carriers can leverage their existing SONET investments to expand and deliver Ethernet services cost-effectively.”⁴⁵ All the OSI Layer 2 Data Link ‘hardware hooks’ are thus in place for supporting the LAN and the WAN infrastructures within an expanding Ethernet universe migrating from 1 GbE to 10 GbE over the 2002-2005 timeframe. The days of deploying expensive OC-192 SONET hardware employing stratum clocking and requiring stringent jitter performance due to limitations in receiving hardware for new installations are over.

4.1.3 XAUI (10Gb/s), 40 Gb/s Ethernet (40 GbE), and 160 GbE

The 10 Gb/s Attachment Unit Interface, termed “XAUI” (pronounced “zowie”), with the Roman numeral “X” indicating “10” for 10 Gb/s, was also defined by the IEEE 802.3ae 10 Gb/s Ethernet Task Force. The XAUI interface dramatically improves and simplifies the routing of electrical interconnections for SERDES (serializer-deserializer), ASIC (Application Specific Integrated Circuit), FPGA (Field Programmable Gate Array), and optical module interfaces and is well on its way to becoming the universal 10 Gb/s interface for all hardware. It largely mitigates data-skew offsets, and permits the “plugfest” (the ability to use any module from any vendor that adheres to the standard) capability so desired by users. Instead of providing a single serial 10 Gb/s interface as provided in the WAN PHY definition of 802.3ae, XAUI uses four 3.125 Gb/s differential pairs to provide 10 Gb/s throughput capability. The XAUI has also been selected as the interface for the 10 Gb/s Ethernet Z-Axis Pluggable Module MSA (Multi-Source Agreements) XGP and XENPAK.⁴⁶ The first XAUI MSA Module Transceivers at OC-192 (10 Gb/s) were developed in late 2000 through early 2001, and deliveries started in mid 2001 from the major manufacturers (JDS Uniphase, *et al*). As of 2002, over fifteen vendors have entered the XAUI MSA Module market and are producing transceivers. Major vendors plan to make transponders (i.e., transceivers with CDR functionality) with XAUI interfaces available in 2002. In 2003, nearly all current XAUI MSA Module transceiver vendors will provide transponders.

Another 10 Gb/s interface worthy of note is the 10-Gigabit Small Form-Factor (SFF) Pluggable Multi-Source Agreement (MSA) Module (XFP) interface known as XFI. The

⁴⁵ Oliva, Val. *Ethernet, The Next Generation WAN Technology*. Version 1.0, p. 10, May 2002. Foundry Networks and 10G Ethernet Alliance. <http://www.10gea.org/SP0502NextGenerationWAN.pdf>. Retrieved 3 June 2002.

⁴⁶ http://www.10gea.org/XAUI-An%20Overview_0302.pdf

governing specifications for this module and its interface were developed by the 10-Gigabit SFF Pluggable Module Group MSA Association. The existence of this group, comprised of ten founding member companies: Broadcom Corporation, Brocade, Emulex Corporation, Finisar, JDS Uniphase, Maxim Integrated Products, ONI Systems, ICS (a Sumitomo Electric company), Tyco Electronics and Velio, was publicly announced in March 2002 at the Optical Fiber Conference (OFC) in Anaheim, CA. Finisar Corporation publicly demonstrated the first prototype XFP Module at the OFC 2002 show. Since the initial public announcement at OFC, additional member companies have joined, and as of May 2002, the group has grown to forty-four companies. The group's purpose is to develop a common specification for multi-sourcing an application-agnostic, ultra-small form factor, 10 Gigabit per second (Gb/s) module for the telecommunications, data communications and storage area network (SAN) markets, supporting OC-192/STM-64, 10 G Fiber Channel, G.709, and 10 G Ethernet, all usually supported with the same module in different native modes of operation. The functionality will be such that support for 10 Gb/s Ethernet will be one of the native modes provided within XFP modules, thereby reducing the entry cost for obtaining 10 Gb/s Ethernet hardware. The primary difference between the XFI/XFP Module interface and the earlier XGP interface is the transition to a small form factor (SFF) in the XFP. Because many of the same companies working to support XFP also developed XGP, the lessons learned while developing XGP will help reduce the risk of new XFP developments.⁴⁷

Next on the roadmap for development are the 40 Gb/s (OC-768) Ethernet specifications. OIF (Optical Internetworking Forum) industry-wide working group meetings commenced in mid-2001, and are continuing through 2002, to develop the next generation of Ethernet specifications at OC-768. Multiple 40 Gb/s interconnection architectures are being planned and discussed, including 16-wide 2.5 Gb/s, as well as 4-wide 10 Gb/s pathways. For now, the 16-wide OC-48 version looks to be the most promising, as it allows the use of lower-cost and lower power-consumption CMOS (Complementary Metal Oxide Silicon) SERDES chips. Still, the four-wide SiGe (Silicon Germanium) architectures, such as proposed by Intel/GIGA, Infineon, and a few other vendors, are likely to co-exist, at least for a while if not indefinitely, until all the economic issues are resolved and 40 Gb/s Ethernet standards are finalized. Finalization will likely not occur until after 2004-2006, due to the economic slowdown in telecom spending that started in early 2000.

The early stage plans for OC-3072 (160 Gb/s) Ethernet are presently being discussed. This technology will probably not be seriously worked until after the OC-768 Working Group disbands, around 2006-2008. The first of these systems will not be available until 2008-2010 at the earliest, if their data-handling capabilities make economic sense. (If

⁴⁷ XFP MSA Organization Website, <http://www.xfpmsa.com/cgi-bin/home.cgi>, retrieved 21 May 2002. Also, see http://www.lightreading.com/document.asp?doc_id=15377 for the XFP news release dated 20 May 2002 from Finisar Corporation.

there is no market for these data rates in Ethernet applications, then their development will not occur.)

4.1.4 **DOCSIS and DSL**

DOCSIS (Data Over Cable Service Interface Specification) is a Cable Modem protocol specification, analogous to SONET and ATM, which provides another transport method of Ethernet protocol signals.⁴⁸ DOCSIS includes networking support for computers specifically communicating through Ethernet protocols, as well as for HDTVs (High Definition Televisions) and set-top TV boxes (such as for pay-per-view services). The DOCSIS 1.0 cable modem specification was approved by the ITU in March 1998. Within just nine months (by the end of 1998) there were 1.2 Million cable modems already installed within homes in the United States, providing the first widespread broadband Internet connectivity services to the home in the United States. Market forecasts predict 24.3 Million cable modems will be installed in US homes by 2004.⁴⁹ Although this number seems ambitious, it is likely to be achieved. In April 2002, Cable Modem users in the US already numbered 7.7 million versus 4.9 Million for DSL users.⁵⁰ Further, the number of new Cable Modem users is increasing much faster than the number of new DSL users. DOCSIS is therefore rapidly becoming the dominant broadband technology in the US.

DOCSIS defines downstream data transfer rates of 27 to 36 Mb/s over frequencies from 50 MHz to 750+ MHz and upstream data transfer rates of 320 Kb/s to 10 Mb/s from 5 to 42 MHz. This high speed data transfer is implemented in Cable Modems that connect to the 75-Ohm physical coaxial line of the cable TV provider and which provide a two-way output Ethernet port in a Cat-5 compatible RJ-45 socket, providing a high-speed Ethernet connection. As originally used by many home users, the output of the Cable Modem was often simply connected to an Ethernet NIC (network interface card) on a personal computer. This still works, but is not considered secure by modern networking practices.

An older high-speed physical layer protocol is DSL (Direct Subscriber Line). DSL still provides the only significant alternative to cable modems for providing high-speed computer networking, and can provide bi-directional data transfer rates up to 32 Mb/s

⁴⁸ The major transport technologies over the past decade have included: SONET, ATM, T1, T3, and frame relay. Even older transport protocols included ISDN, X.25, and AX.25. ISDN (Integrated Services Digital Network) was developed as a high-speed, 64 Kb/s service for sending voice, video, and data simultaneously over telephone lines. Most ISDN services actually provide two simultaneous 64 KB/s lines, for 128 Kb/s, total. The X.25 protocol was intended for a closed, coaxial-cable system WAN, and AX.25 was intended for a WAN coverage via a wireless RF link, supported through digital repeaters (digipeaters). AX.25 was developed in the Amateur Radio marketplace, but spread quickly to the Department of Defense (DoD) for use in early VHF packet radio systems operating at relatively low bit rates (1200 b/s to 9600 b/s).

⁴⁹ <http://www.webopedia.com/TERM/D/DOCSIS.html>

⁵⁰ Mowrey, Mark. *Coming soon to your cable box: built-in wireless networking*. Red Herring, July 2002, p. 23.

over ordinary phone lines. In spite of a nearly 3:1 theoretical advantage over DOCSIS 1.0's upstream data transfer rates of 10 Mb/s, DSL has captured only a small fraction of the total market share. Due primarily to a failure to get hardware built and fielded quickly enough, DSL and xDSL – which is a more general technology – are not a significant factor within the US at this time. DOCSIS started from behind, with poorer performance, and still managed to capture nearly all the market within only about eighteen months. In spite of providing theoretically higher bi-directional data rate performance than DOCSIS 1.0 was capable of providing, all indications are that xDSL is a technology that has largely been overcome by a failure to deliver DSL modems fast enough to capture market share. Making matters worse, DOCSIS 1.1, the latest version of the DOCSIS standard, now provides 54 Mb/s connectivity, the same as 802.11a and 802.11g Wireless Ethernet, beating DSL's performance by 50%. The window of acceptance for DSL is closing. As DSL is not likely to be a dominant WAN PHY technology going in the future, it will not be discussed further in this report. The disruptive technology of DOCSIS has largely already replaced DSL, through providing high-volumes of lower cost modems, thus capturing the high-speed Internet-to-the-home market.

The primary concern with directly connecting a computer to a high-speed Ethernet WAN, with 24/7 connectivity, whether with DOCSIS or DSL, is security. Port probes of Ethernet WAN-connected computers by individuals attempting to obtain unapproved access to these computers are a real threat. In the fall of 1999, the numbers of 'hits', measuring the number of attempts to obtain surreptitious access to such connected computers, was typically no more than two or three tries per day on a Cable Modem system. As of May 2002, the number of attacks has increased to upwards of fifty to sixty attacks per day, an increase of over twenty times.⁵¹

Initially, the only way to protect such 24/7 connected computers was through the use of firewall software, such as BlackICE Defender®, or ZoneAlarm®.^{52,53} During 2000, with the numbers of attacks rising, and to reduce LAN network congestion from the attacks, the need for hardware solutions became obvious. By 2001, Cable/DSL Routers, intended for sharing high-speed computer networking among several co-located computers through a common Cable Modem, became available. By late 2001, functionality for newer Cable/DSL routers was increased to provide NAT (Network Address Translation) firewall functionality. With NAT firewalls, the isolation between the LAN and the Cable WAN provides an additional layer of protection, in addition to the software firewalls. Since Ethernet attacks through a router are possible, NAT firewalls, though, do not

⁵¹ These numbers are for Time Warner Cable's RoadRunner service in Brevard County, Florida. High-speed cable modem service was first installed in parts of Brevard County, Florida in the summer of 1999.

⁵² BlackICE Defender® is now BlackICE PC Protection® and has been acquired from Network ICE by Internet Security Systems (ISS) as of June 6, 2001. See: http://www.iss.net/products_services/hsoffice_protection/blkice_protect_pc.php.

⁵³ ZoneAlarm® is a product of Zone Labs. See: <http://www.zonelabs.com/products/za/> It is free to non-commercial users, and private individuals.

provide entirely adequate security to secure LANs connected to an Ethernet WAN through a Cable Modem, or as discussed shortly, a Fiber Modem. In addition, as discussed later in the Wireless Ethernet section, the installation of a Wireless Ethernet Access Point (WEAP) behind a physical NAT firewall also threatens system security through a backdoor that must be protected, as well. Protection within a LAN behind a firewall, whether against wired or wireless Ethernet attacks, still often requires software-based firewalls be installed for adequate security for many applications.

Just one company, Broadcom, largely dominates DOCSIS chip sets. Broadcom is the acknowledged DOCSIS industry leader, with over 80% market share as of late 2001.⁵⁴ (Broadcom also wrote the original drafts of what became the DOCSIS 1.0 standard.) Broadcom's chip sets are also being used to implement Ethernet functionality over SONET SR (Short Reach) and LR (Long Reach) fiber-optic links with Fiber Modems, functionally equivalent to Cable Modems, operating over SMF (single-mode-fiber) in place of 75-Ohm coax, to support Ethernet transport over high-speed DWDM (Dense Wavelength Division Multiplexing) optical networks.

The trend is obvious; DOCSIS will increase in importance for providing PHY layer wired Ethernet transport, and will further reduce the cost of systems needed to implement Ethernet transport over high-speed, broadband networks. As discussed later under Wireless Ethernet, the next generation of Cable Modems and Cable TV set-top boxes will also contain built-in wireless networking, enabling sharing of video, data, and audio content throughout the SOHO environment from a single Cable Modem/Set-top box. This addition of wireless connectivity will likewise reduce the market share of DSL technology relative to Cable Modem technology.⁵⁵ In Spaceports of the future, where Wireless connectivity fed through Cable Modems *and* Fiber Modems is likely, firewall solutions employing both hardware and software implementations will be necessary to provide adequate security of Ethernet connections.

4.2 WIRELESS TECHNOLOGIES

Looking beyond the next five to seven years, three major types of wireless systems are likely to provide nearly *all* of the data networking needs of Spaceports and Ranges in the not so distant future:

- WPAN systems
- 3G (3rd Generation) Wireless systems

⁵⁴ <http://www.broadcom.com/cablemodem.html>

⁵⁵ Mowrey, Mark. *Coming soon to your cable box: built-in wireless networking*. Red Herring, July 2002, p. 23.

- WPAN, LAN, and WAN mixed capability systems

WPAN (Wireless Personal Area Network) systems, typified by Bluetooth and Zigbee, are intended for low data-rate, short-distance communications. Due to technical limitations, WPANs cannot provide wireless versions of competitive LAN (Local Area Network) or WAN (Wide Area Network) services on future Spaceports and Ranges. On the other hand, although they are not necessarily configured into WANs, 3G (3rd Generation) Wireless services *are* intended to provide services over wide areas.

The FCC (Federal Communications Commission) plans to conduct “spectrum auctions” (i.e., the sale of licenses) for 3G Wireless services in September 2002. In Europe, similar spectrum auctions held in 2000 for 3G Wireless services resulted in raising revenue to the tune of billions, to tens of billions of US dollars (USD) per company, depending on the country/countries. The total European government ‘take’ for 3G licenses was approximately \$180 billion (USD). The European 3G Wireless spectrum auction timing was unfortunately at the very peak of the telecommunications market ‘evaluation bubble’, and 3G licenses sold at overly high valuations. With the subsequent worldwide telecommunications market downturn seen in 2000 and 2001, the result, as of mid-2002, has been both a consolidation among existing European 2G Wireless companies that won 3G bids, and the bankruptcy of many companies. The high prices paid for licensure, the subsequent slowness of the European 3G market to take off, and the resulting slow cash flows, have been simply too much for many of the successful 3G Wireless bidders to weather the ‘perfect storm’ of the telecommunications market melt-down. The result has been a very slow 3G Wireless services rollout, due both to high licensing costs and, as it turns out, somewhat limited technical performance. The outcome: 3G Wireless service companies have not been successful. Likewise, US companies planning 3G Wireless services have watched in horror as their European counterparts have folded, or, to stave off bankruptcy, have been forced to consolidate. This does not bode well for the FCC’s planned auction of 3G Wireless.

The likely outcome, at least in the US, is that there is only one contender in terms of performance and cost for implementing high performance LANs and WANs in the near future: namely, Wireless Ethernet. Unlike planned 3G Wireless services, the spectrum for Wi-Fi is unregulated and freely available to all. Thus infrastructure costs for Wi-Fi have an inherent advantage ‘out of the gate’ relative to 3G Wireless, with very much higher performance than even *planned* for 3G Wireless services. In addition, over the last few years, the rapid rise of Wireless Ethernet has been nothing short of phenomenal. With low-cost, unregulated Wi-Fi equipment now available, the *guerrilla wireless winner*, winning the unconventional wireless war, is Wireless Ethernet.^{56,57} The present

⁵⁶ Hanfit, Adam. *ALL THE NEWS THAT DIDN'T FIT*. Worth Magazine, p. 84, May 2002. Worth.com

⁵⁷ *Guerrilla* comes from the Spanish root word *guerra*, meaning war; hence, *guerrilla* means ‘little war.’ Guerrilla warfare concepts first became formalized in the first half of the 19th Century, in multiple fights for colony independence across South America. With guerrilla warfare, small, mobile forces defeated superior, larger, well-established European-trained conventional forces. The concept was then exported

leader, as well as the long-term likely ‘big’ winner in the WAN market space, even over 3G Wireless, is Wireless Ethernet. For that reason, Wireless Ethernet is a major focus of this section, although the WPAN technologies of Bluetooth and Zigbee, as well as 3G Wireless, are also discussed in detail.

4.2.1 Wireless Ethernet (Wi-Fi)

Wireless Ethernet equipment, dubbed Wi-Fi in the popular press, is predominately governed at present by the IEEE 802.11b High Rate WLAN Standard.⁵⁸ First available in the marketplace in 1999 at very high prices, Wi-Fi equipment prices have since quickly dropped. Wi-Fi Adaptor cards for laptops now are priced at well under \$100 (PCC/PCMCIA form factor). Wireless Ethernet Access Point (WEAP) devices (i.e., base Wi-Fi Adaptor units) are also inexpensive, costing around \$125- \$200 (May 2002) for single-mode Access Point devices intended for use with wired, networked computers. Together, these Wi-Fi adaptors greatly simplify the wireless connectivity issues that exist while forging a total network solution among wired and wireless connected computers. The result is that implementing an overall wired and wireless network that operates much like a conventional, wired network, has become easy and very inexpensive.⁵⁹

Network Interface Card (NIC) Adaptors for 802.11b come in three configurations in two basic form factors. For laptops, there are PCC/PCMCIA Wi-Fi adaptor cards. For desktops, there are USB port adaptor cards available, as well as standalone Wi-Fi Access Point devices. In addition, there are also PCI adapters for desktops that permit plugging PCMCIA Wi-Fi cards intended for laptops into a PCI Slot inside a desktop in Windows 98/SE/ME systems.⁶⁰

back to Europe, especially to Spain and Italy, due to such European leaders as Garibaldi of Italy, who lived for many years in South America, participated as freedom fighters, learned guerrilla warfare tactics, and returned to Europe. Today, *guerrilla wireless* represents a similar fight for roaming wireless user independence in America against the bureaucratic control of wireless infrastructures. There is a strong likelihood of economic impacts occurring soon in Europe as Wireless Ethernet expands there, in a direct historical parallel to the adoption in Europe of the original guerrilla warfare tactics developed in the Americas. This economic impact will likely be against the 3G Wireless regulated companies that have spent the equivalent of tens of billions to hundreds of billions of US dollars in Europe to secure 3G Wireless licensing. For an historical perspective on Giuseppe Garibaldi’s education in guerrilla warfare from 1836-1848 in South America, see: <http://www.sc.edu/library/spcoll/hist/garib/garib1.html>.

⁵⁸ Wi-Fi is an obvious wordplay of Wireless Fidelity that plays off the older Hi-Fi term denoting High Fidelity used for early stereo equipment and sound recordings. In addition, there is the modern wordplay of “Wireless” with “Fiber”.

⁵⁹ For comparison, the Intel 5000 LAN Access Point (WEAP) for the newer 54 Mb/s Wi-Fi 5 (802.11a) retails for \$449, while 54 Mb/s PC cards retail for \$179 (March 2002.) These prices are comparable to the prices of early 802.11b devices. For comparison, current 802.11b prices have fallen such that the total price for an 11 Mb/s Linksys Wireless Access Point (WAP-11) and its associated 11 Mb/s PCMCIA Linksys Wi-Fi card, is under \$275, combined, retail.

⁶⁰ These **DO NOT** typically work on Windows 2000 or Windows NT, at least not with present cards.

Wireless network interface card adapters for 802.11b operate in one of two modes: Ad-Hoc Mode or Infrastructure Mode. Infrastructure Mode is the default mode used unless otherwise de-selected during initial setup. This mode routes all traffic through a WEAP that controls encryption on the network and that may bridge or route wireless traffic to a wired Ethernet network (or the Internet). WEAPs that act as routers also can assign IP addresses to connected PC's. WEAPs come in three varieties -- Bridge, Network Address Translation (NAT) Router and NAT Router + Bridge.⁶¹ Bridge-type WEAPs transparently connect a wireless network to a wired network and provide bi-directional communication. A NAT Router is a unidirectional WEAP that can route traffic from the wireless network to an Ethernet wired network, but which will not route traffic back to the wireless network.⁶² The third type of WEAP device is a hybrid NAT Router + Bridge, also known as a Wireless Cable/DSL router, that provides single-IP address connectivity for both wired and wireless networks. This third type of WEAP is often used for sharing an Internet connection among both wired and wireless interconnected computers in a single private home. Infrastructure Mode (with Bridge *or* NAT Router + Bridge type WEAPS) is the normal mode used for providing public Wi-Fi connectivity.⁶³ Slight variants of this third type of WEAP device also can serve as a WEAP router for splitting an existing wired 10/100 Ethernet network, utilizing a USB (Universal Serial Bus) port interface for initial set-up, only, and then utilizing a CAT-5 interface cable for interconnecting a port of a wired 10/100 Ethernet switch hub sitting on an existing wired network to up to 32 wireless devices. Although two internal antennas are available, such devices also permit using one or both internal antennas, or of connecting one or two remote antennas in place of either (or both) of the short, stubby "rubber-ducky" antennas on the back of the device, to extend the range of the equipment. If NAT functionality is not desired, configurable DHCP (Dynamic Host Configuration Protocol) address assignments to wireless devices can be provided by the existing network. Such devices can also be configured to provide point-to-point bridge functionality, to enable, for example, a wireless point-to-point connection between two remote networks, especially if two high-gain, directional antennas are connected to the device, pointing in different directions, achieving in essence an Ethernet digital repeater. If they are so configured, though, these bridge-configured WEAP devices cannot then provide Infrastructure

⁶¹ Network Address Translation (NAT) routers function to translate an Internet Protocol (IP) address used within one network to a different IP address known within another network. One network is designated the *inside* network and the other is designated the *outside* network. Typically, NAT routers map both local *inside* network addresses to a global value and unmap incoming global *outside* IP addresses on incoming packets into local IP addresses to ensure security. NAT functionality also conserves the number of global IP addresses that would otherwise be needed, and permits an inside network to use a single IP address in its communication with the world. NAT routers greatly simplify Internet communication. NAT routers provide a hardware firewall, thereby reducing the processor loading on gateway machines with software firewalls installed.

⁶² This is most suitable for limited, one-way, pager-style communication.

⁶³ <http://www.homenethelp.com/802.11b/index.asp>

connectivity for multiple wireless devices in addition to bridge functionality. Another variant of this third type of WEAP provides built-in switch functionality, with 4, 5, or more, wired port outputs enabling several remote users to connect into a wired LAN off the remote WEAP. The primary difference, in choosing the third variant with or without a switch built-in, is whether 1:N (probably benefiting from a built-in switch) or N:1 (no built-in switch needed) connectivity is desired. With the flexibility presently available, it obviously can become a daunting task to select the optimal hardware to construct a wired/wireless network for the average home-user with multiple laptops and desktops, a single cable/DSL modem, a switch or two, and firewalls already in place on a wired network. Fortunately, in spite of possibly selecting less-than-optimal functionality WEAP equipment, there is usually enough overlap in features and enough flexibility in practice, such that the average user can easily obtain entirely satisfactory results once WEAP and PCMCIA Wi-Fi equipment is purchased and installed.

In Ad-hoc Mode, two or more Wi-Fi equipped computers may communicate directly with each other without a WEAP in a peer-to-peer arrangement. However, for this to work, the individual wireless cards in each Wi-Fi equipped computer must be set to 'Ad-Hoc' mode instead of the default 'Infrastructure' mode. Ad-hoc mode is suitable only for the smallest private Wi-Fi systems, where limited utilization (e.g., a single roaming wireless user) is all that is to be supported.

In either the Infrastructure or Ad-Hoc mode, IEEE 802.11B 11 Mb/s High Rate wireless Ethernet Wi-Fi equipment provides performance that is very nearly the same as that provided by the older, legacy 10BaseT wired equipment that provided 10 Mb/s connectivity. However, unlike the older legacy equipment, the flexibility of use is considerably more with Wi-Fi, since users can now roam throughout their coverage area, and are no longer tied to just one physical location or desk.

The Wireless Ethernet Compatibility Alliance (WECA) was formed in August 1999 with just six member companies.⁶⁴ It is now comprised of over 130 member companies, and has declared its mission to certify interoperability of Wi-Fi (IEEE 802.11) products and to promote Wi-Fi as the **global** wireless LAN standard across all market segments.⁶⁵ With nearly 200 certified devices as of September 2001, its success in terms of certifying interoperability has been significant.⁶⁶ In further support of the long-range goals of their mission, WECA has recently petitioned the Federal Communications Commission (FCC) to permit unlicensed national operation of new equipment providing even higher data rate

⁶⁴ http://www.wirelessethernet.org/pr/pr_pdf/Wi-Fi_Fall_01_Briefing.pdf

⁶⁵ Older wireless Ethernet equipment, with 2 Mb/s data rates using direct sequence spread-spectrum operation in the 2.4 GHz ISM band, has been in existence for many years, and not all newer 11 Mb/s High Rate equipment is completely compatible with this older equipment. Starting with 11 Mb/s speeds, though, WECA is now working this interoperability issue to avoid the future obsolescence of 11 Mb/s, and faster, equipment.

⁶⁶ http://www.wirelessethernet.org/pr/pr_pdf/Wi-Fi_Fall_01_Briefing.pdf

operation in the range of 5.470-5.725 GHz.⁶⁷ This petition, filed January 15, 2002, has been assigned the Rule Making number of RM-10371 by the FCC. If approved, the WECA plan is to increase data throughput for Wi-Fi to around 100 Mb/s, or higher, typical, going to greatly higher data rates within just a few years, for its next steps up in data rate, analogous to the historical step taken going from 10 Mb/s 10BaseT to 100BaseT that occurred in the wired Ethernet world. The newest version of wireless Ethernet presently available is referred to as Wi-Fi 5.⁶⁸ Under perfect conditions, it runs at a maximum theoretical speed of 54 Mb/s. A new IEEE 802.11a standard governs the details of this faster Wi-Fi. The 802.11a modulation technique is OFDM (orthogonal frequency division multiplexing), unlike the 802.11b, which uses DSSS (direct sequence spread spectrum). The advantage is that OFDM operation allows packing more bits per second than DSSS into the same operating bandwidth with a single set of transmitter and receiver hardware.⁶⁹ To reduce network congestion, OFDM modulation also will permit the simplification of routing, for 802.11a routers, once the need arises.

The naming of both WECA and even of Wi-Fi 5 has met with confusion in the marketplace. “Wireless Ethernet” is a term that has largely been replaced in the public’s mind with the “Wi-Fi” term. The success of the Wi-Fi moniker in marketing terms has been at the loss of recognition for the underlying technology, Wireless Ethernet. Customers simply want to be wirelessly connected, and “Wi-Fi” is the term for which they search when attempting to buy a product. Attempting to change the underlying descriptive term from version to version simply confuses the average buyer standing in front of a Wi-Fi display in a store. The question asked by many, upon hearing the “Wi-Fi 5” term for the first time, is what happened to Wi-Fi 2, 3, and 4? In addition, the typical customer assumes (wrongly) that Wi-Fi 5 should be backwards compatible with Wi-Fi (it is not.) Taken together, this indicates a clear misunderstanding that the 5 in Wi-Fi 5 refers to the 5 GHz band in which Wi-Fi 5 operates, in contrast to the 2.4 GHz band in which Wi-Fi first emerged, which the public never knew in the first place. The further explanation that the ‘5’ in Wi-Fi 5 is not the version number of Wi-Fi being indicated simply confuses the issue more. When a typical customer learns that Wi-Fi 5 is not backwards compatible with Wi-Fi, the usual response is a sense of hostility and frustration. Clearly, these issues must be resolved prior to releasing Wi-Fi 5 hardware to the retail market. A new name is needed.⁷⁰

⁶⁷ <http://www.wirelessethernet.org/index.html>

⁶⁸ The “5” indicates it uses the 5 GHz band, instead of the older 2.4 GHz ISM band used for 802.11b which is co-shared with numerous unlicensed FCC Part 15 devices such as cordless telephones, microwaves, etc.

⁶⁹ Theoretically, DSSS could pack the same number of bits into the same bandwidth as OFDM, provided that multiple DSSS carriers were overlaid, through using parallel transmitter and parallel receiver technologies, although, in practice, the leakage between parallel signals would negate some of the possible theoretical performance. OFDM thus represents a lower-risk technical solution to the problem, making OFDM more suitable than DSSS for high-volume production of 54 Mb/s Wi-Fi devices.

⁷⁰ Junko Yoshido. *Group proposes catchall 802.11 labeling*. Electronic Engineering Times, 15 July 2002, p. 1, p. 94.

In an attempt to clarify Wireless Ethernet terminology to the public, and even to vendors who only do Wi-Fi product development, WECA itself is planning to change its name from WECA to the “Wi-Fi Alliance”. Likewise, WECA’s original plan of indicating Wi-Fi 5 compatibility, through stamping a Wi-Fi 5 seal of approval sticker on boxed equipment, is not going to be used. Instead, “Wi-Fi” will become the basic compatibility sticker used, with versions of Wi-Fi indicated by the terms 802.11b, 802.11a, 802.11g, etc., analogous to Win98[®], WinNT[®] and other terms used to indicate particular versions of Windows[®]. Wi-Fi will thus become the generic term for Wireless Ethernet, analogous to the generic term of Windows[®] used for indicating Microsoft’s operating systems.^{71,72}

Another Wi-Fi technology scheduled for release within the next year is IEEE 802.11g. It runs at the same 54 Mb/s theoretical maximum data rate as 802.11a, and also uses OFDM modulation, but will operate in the same 2.4 GHz frequency range as the existing 802.11b devices. The ultimate plan for 802.11g is to provide seamless interconnectivity between existing 2.4 GHz 802.11a devices at 11 Mb/s with future 2.4 GHz 802.11g devices capable of 54 Mb/s, without obsolescing any of the older 802.11a devices. Future 802.11g wireless access points (WAPs) will therefore include both DSSS modulation support and OFDM support, to provide backwards compatibility with legacy 802.11b WNA (Wireless Network Adaptor) devices, as well as future support for planned OFDM-based routers.

As for 5 GHz 802.11a devices, backwards compatibility to 802.11b protocols is now possible, permitting the continued operation of already-installed 2.4 GHz 802.11b devices. The first Dual-Band Wireless Access Point device became available August 20, 2002 with the introduction of the Linksys WAP51AB. Priced at \$299, this Dual-Band Wireless Access Point permits users to support their present investment in 802.11b devices, while providing an upgrade path to the less-crowded 5 GHz band, and to the faster throughput provided by the 802.11a mode of operation.⁷³ As to whether the 802.11a standard or 802.11g standard will ultimately win the majority of market share in providing 54 Mb/s high speed Wi-Fi, only time will tell. Yet, the planned 802.11g advantages, to provide backwards compatibility to 802.11b devices, in addition to connecting new 54 Mb/s 2.4 GHz 802.11g devices, will likely mean that the 802.11g standard may ultimately become dominant over the 802.11a standard. If so, 802.11g will win market share for applications where cost advantages in supporting operation in only

⁷¹ Ben Charny. *Wi-Fi Group Clears Up Naming Confusion*. CNET News, 18 July 2002, http://news.com.com/2100-1033-945023.html?tag=fd_top, retrieved 29 August 2002.

⁷² Sam Costello. *Group may change name of 802.11 certification*. IDG News Service, 19 July 2002, <http://www.nwfusion.com/news/2002/0719weca.html>, retrieved 29 August 2002.

⁷³ Linksys Press Release. *New Dual-Band Wireless Access Point Connects IEEE 802.11a and 802.11b Wireless Networking Devices With a Cost Less Than Most 802.11a-Only Access Points*, <http://www.linksys.com/press/press.asp?prid=83&eyear=2002>, dated 20 August 2002, retrieved 28 August 2002.

one band dominate in spectrally unoccupied locations, such as SOHO applications. With operation in only one band, the recurring cost savings possible by eliminating an additional RF front-end, RF power amplifier, and antenna for a second band should prove beneficial for 802.11g. However, due to lessened susceptibility of interference of 802.11a standard devices operating in the 5 GHz band, the 802.11a protocol may still win in business applications in spite of a higher cost, due to increased throughput performance in spectrally crowded office environments. After all, relative to an increasingly crowded 2.4 GHz band for 802.11g, 802.11b, microwave ovens, cordless phones, and other 2.4 GHz ISM devices, the 2.4 GHz band Wi-Fi protocols will likely suffer from lessened throughput relative to the 5 GHz 802.11a band. As a result, the market will likely split, allowing both 802.11g and 802.11a devices to coexist in different market spaces, with both providing dual-mode operation sharing with legacy 802.11b devices, due to cost advantages in 802.11g for SOHO use and to 5 GHz band performance advantages in 802.11a for regular office use.

Wi-Fi (802.11b) data transfer throughput is a function of the range from the base. Near the base, data transfer throughputs of 11 Mb/s are achieved for 802.11b. Practical indoor operational distances range up to 25-150 meters (75-450 feet) from the base, over which Wi-Fi is typically found to operate well, usually provide data transfer throughputs from 3.5- 4.5 Mb/s. It is possible to specify in most of the Wi-Fi hardware available today how to handle this throughput data rate versus range capability. As normally configured, four steps (from 2.5 Mb/s to 11 Mb/s) can typically be set to adapt automatically to changing link margin conditions, while providing maximum throughput. On the other hand, it is also possible to lock the minimum data rate to some user-selectable rate among the four data rates provided, to maintain a minimum throughput, if any throughput exists, although this is not a commonly selected configuration. Provided that the system is allowed to adapt, as the user roams closer to the edge of Wi-Fi communication range, the data transfer rate often drops to around 2.5 Mb/s to 4 Mb/s, with just a few intervening walls setting the practical distance limit that can be roamed in many instances. Outdoor ranges up to 600 meters (1800 feet) are often possible, at rates from 4 Mb/s to 11 Mb/s, under perfect conditions.

Whereas 802.11b sometimes provides a range of 100 to 150 feet indoors at its top speed of 11 Mbps, the faster Wi-Fi 5 (802.11a) can theoretically achieve only around 60 feet at its top speed. However, 802.11a users still theoretically achieve two times the throughput performance of 802.11b at the same distance. (The same will be true for 802.11g.) With a top speed of 54 Mbps, at distances greater than 60 feet up to around 120 feet, 802.11a theoretically only falls back to a still impressive 24 Mbps. At farther distances, 802.11a speeds further decrease to 6 Mbps, which is comparable to 802.11b's real-life top performance of 4 Mb/s often seen in practical installations.

First generation WLAN security, denoted as WEP (Wired Equivalent Protocol, or Wireless Encryption Protocol, depending on vendor), is variable, depending on the exact vendor hardware selected. Encryption using 40 bit, 64 bit, and 128 bit keys are all used

depending on the vendor, with no guarantees as of yet of complete interoperability between vendors of their various full-strength encryption techniques.⁷⁴ Provided WEP is used, however, data transfer throughput is reduced about 20-50% in most instances. In other words, the practical indoor 802.11b data rate of about 3.5-4.5 Mb/s seen without WEP enabled drops to around 2.5-3.5 Mb/s with 128-bit WEP enabled. On the other hand, with 64-bit keys selected, a negligible drop is often seen at close ranges (between neighboring rooms, for example.) The degree of security provided by WEP is marginal, although probably adequate for many SOHO (Small Office Home Office) users.

With the 50% reduction in data throughput often seen, however, full WEP is often disabled in practice just to speed up wireless networks, and total dependence on security through ever-decreasing obscurity of the 802.11b protocol is the result.⁷⁵ A likely necessary step to implement WEP fully in most commercial installations will be to change from 802.11b equipment without WEP to 802.11a or 802.11g equipment with WEP, or whatever replaces WEP. In practice, the data transfer throughput will be nearly the same, and users may not even be aware that encryption has been activated. At the same time, security will be enhanced. The wireless LAN (WLAN) threat is real, especially with the recent widespread introduction and availability of WEP security-cracking tools on the Internet such as Netstumbler, Aircrack, and WEPcrack.^{76,77,78} These are passive tools that require only an afternoon's typical volume of traffic (i.e., around 10 to 100 Million packets) to compromise an 802.11b network and obtain full network access.⁷⁹ First generation vendor-supplied solutions to the WEP-cracking threats are not

⁷⁴ Due to differences in how key bits are counted, 64 bit systems actually provide the same number of key bits, i.e., 40 bits, as are used in what are called 40 bit systems. It is merely a difference in semantics, not a difference in degree of protection. Likewise, selecting keys through pass phrase selection between vendors is also not guaranteed to provide interoperability between Wi-Fi-certified systems made by different vendors. Instead, cryptographic keys must be entered by their hexadecimal values to meet Wi-Fi certification requirements for achieving interoperability when using WEP.

⁷⁵ Early experiments done at Harris Corporation (parts of which are now Intersil) with prototype Prism™ chipsets during the early to mid 1990's, prior to the public release of 802.11b, were actually fairly secure! *Prism* itself is technically an acronym for **P**acket **R**adio **ISM**, where ISM (Industrial, Scientific, Medical) is the generic description of the 2.4 GHz unlicensed band where the first of these devices operated. 'Packet radio' itself is a term referring to earlier AX.25 protocol transmissions using militarized versions of amateur (ham) radio terminal node controllers (TNCs) developed during the packet radio developments from the mid-1980's. The early 1980's AX.25 protocol was the Amateur radio modified version of the even earlier European X.25 communication protocol, modified for radio use. Wi-Fi is thus a logical descendant of the European X.25 protocol, with a firmware and specification development period having been spent in the ham radio communities around Melbourne, Florida and Tucson, Arizona, as well as at Harris Corporation and Intersil in Palm Bay, Florida (near Melbourne.)

⁷⁶ <http://www.netstumbler.com/>

⁷⁷ http://www.wirelessethernet.org/pr/pr_pdf/Wi-Fi_Fall_01_Briefing.pdf

⁷⁸ <http://www.itsecurity.com/asktecs/sep1301.htm>

⁷⁹ <http://www.newsfactor.com/perl/story/13102.html>

expected until late in 2002. One of the possible solutions is TKIP (Temporal Key Integrity Protocol). TKIP is able to change keys on the fly approximately every 10,000 packets, unlike WEP. TKIP is presently (as of May 2002) going through the IEEE standards process, where it is to be known as 802.11i.⁸⁰

Another possible solution to WLAN security is proprietary (i.e., vendor-specific) VPN (Virtual Private Network) client technology adapted for use by wireless roaming users to allow roaming between access points without re-authentication, in a VLAN (Virtual Local Area Network).⁸¹ In any case, since Windows XP provides native support for Wi-Fi, continuing security threat code updates to Windows XP, and the other extant operating systems with native support for Wi-Fi, will likely be required to fix the WEP threats that presently exist with currently defined WEP protocols.

Another, somewhat outlandish approach to Wi-Fi security being used by some, as a temporary, stopgap measure until real Wi-Fi security products become available, is FakeAP, a Gnu Public License (GPL) freeware Linux software package. The underlying idea is that if one access point is good, tens of thousands must be better. Similar to using chad in an electronic warfare environment to protect real airplanes against radar-focused attacks, Black Alchemy's FakeAP allows a Wireless Access Point to generate what appears to be tens of thousands of fake 802.11b access points. An authorized user simply hides in plain sight, amongst an electronic barrage of fake beacon frames. FakeAP therefore confuses Wardrivers, NetStumblers, Script Kiddies, and other drive-by undesirables, who are unable to find the real Access Point among the protective camouflage of an electronic assortment of tens of thousands of fake Access Points. This 'security' approach is clearly not an ultimate solution, but it is an interesting approach to achieving protection against drive-by hackers, at the expense of network congestion. This approach would only work in a very lightly occupied Wi-Fi environment. Eventually, it would also tend to attract drive-by hackers, who would be challenged to find the real Access Point. Although FakeAP is clearly not recommended, it does indicate the creativity being spent to solve the Wi-Fi security problem with low-budget approaches.⁸²

In many cases, through individuals desiring to extend wireless private portals for their own laptops, wireless networks have proliferated at the expense of security in what has become a guerrilla wireless movement within many large organizations. This is simply the next step of a long-standing tradition that has gone on in many large commercial

⁸⁰ Nobel, Carmen, *Symbol crashes WLAN security party*, eWeek, , Ziff-Davis Publishing, May 6, 2002, p. 10.

⁸¹ One vendor working this approach is Columbitech AB of Stockholm, Sweden. For more information, see: Nobel, Carmen, *Symbol crashes WLAN security party*, eWeek, May 6, 2002, p. 10.

⁸² Black Alchemy Weapons Lab, FakeAP, Version 0.3, released September 3, 2002, <http://www.blackalchemy.to/Projects/fakeap/fake-ap.html>, retrieved 4 September 2002.

companies for over a decade now, with the tacit support of mid-level Information Technology management.

To understand this recent movement, consider an historical analogy. To stem the unauthorized outflow of company private data in the late-1980's through the mid-1990's many U.S. companies replaced all their analog phone systems with digital systems. With the rapid rise in Internet traffic, many of these same companies additionally installed Ethernet and Web-usage monitoring applications. This way, dial-up modems on laptops could not directly access outside computers, to leak company-private information in real-time, and Ethernet leaks could be detected, too, through monitoring Ethernet connections. FAX machines, though, could not operate over the new digital phone lines. The solution used was to run special analog phone lines just to the FAX machines to allow them to continue to function. Frustrated system administrators, though, quickly learned to install rogue power line analog modems on these same analog phone lines just to access other company-paid-for dial-up services, to access, for example, phone-line secure software security updates to manage Internet-connected servers during major Internet attacks.⁸³ Such power line modems are still sold to connect satellite TV devices to remote phone line jacks located next to a power receptacle to allow users to subscribe to pay-per-view services. They typically operate fairly well at rates up about 33-36 Kb/s, over distances up to 100 feet (30 m) as long as operation through power line transformers is not attempted. Moreover, their use can provide a much-needed method to access special dial-up computer services without having to pay expensive installation fees to install an additional analog phone line for what is (typically) a rare need.

Likewise, many of the same technically savvy individuals that installed phone line modems surreptitiously to access phone-line dial-ups, have repeated the process by installing the first generation of Wireless Ethernet Access Points in a guerrilla wireless movement to provide their groups or staff members access for wireless connectivity, without always acquiring upper level management approval. The countermeasure for this security leak, though, was not long in coming. To prevent unauthorized WEAP devices from being installed and operated without network administration approval on wired networks, which can open an uncontrolled backdoor security threat to an otherwise secure network, it is now possible to acquire a Wireless Protocol Analyzer (WPA) to detect and find such rogue WEAP devices. This presumes, of course, that a private or secured wireless network is desired.^{84,85} For universities, which have historically

⁸³ When a major worm attack occurs on the Internet, the first step in many organizations is simply to sever the Internet connections of all the servers until security patches can be installed. This is exactly what happened in November 1988 with the Morris Worm. Hence, the need for a secure, phone-line dial-up line to secure badly needed Internet server security updates. For more on the first Internet worm, see: <http://www.software.com.pl/newarchive/misc/Worm/darbyt/pages/worm.html>.

⁸⁴ Brooks, Jason, *Wireless LAN Security CRACKDOWN*, eWeek, Ziff-Davis Publishing, May 6, 2002, pp. 45-48.

⁸⁵ Chen, Anne, *Sniffing out rogue wireless LANs*, eWeek, Ziff-Davis Publishing, May 6, 2002, pp. 45-50.

promoted open access to networks and knowledge in general, the use of WPA devices to detect and close down open-access Wi-Fi portals has been met with noticeable hostility. Yet, the haphazard acceptance of new technology without providing the means to insure the security of both the network and of the data flowing on it is certainly risky. The necessity to balance the security needs of an organization, while permitting technological improvement, begs for the highest-level management support and understanding in organizations. Otherwise, technological innovation is simply forced underground, to the approval of mid-level managers, without necessarily achieving all the global needs required for secure computing within many organizations.

One of the newest WPA sniffer devices is by AirMagnet, Inc., and is dubbed AirMagnet 1.2. This product started shipping in April 2002, and costs \$2,495 for a set of software and an 802.11b PCMCIA wireless Ethernet card. Intended for installation on a handheld computer such as the Compaq Computer Corporation's iPaq, this product provides the means to track down rogue Wi-Fi portals. Operating in what is termed full 'tricorder' mode (in honor of the mythical sensor device from the *Star Trek* TV series), scanning all frequencies available for 802.11b devices is provided. In addition, functionality for pinging any WEAPs that are found, to determine whether connectivity to a wired network exists behind the WEAP, is also supported. In 'tricorder' mode, it is possible to ferret out rogue WEAPs in a matter of minutes, without alerting the rogue network that a search is being conducted. This is because AirMagnet 1.2 conducts essentially a passive search, without sending traffic, and sending only occasional pings. With the introduction of such WPA devices, the days of unapproved rogue WEAPs are certainly numbered. In addition, operating WPA devices in 'tricorder' mode also can provide site feasibility information for the installation of authorized wireless network additions, to determine the best coverage versus installation locations, in addition to searching for unauthorized WEAPs.⁸⁶

Although most Wi-Fi networks implemented to date have been private, or, at worst, surreptitious, there is a growing move to provide mobile connectivity *for a price* to roaming Wi-Fi devices through public portals. Such a provider of wireless service is often generically referred to as a WISP (Wireless Internet Service Provider).⁸⁷ First advertised to high-end business-travelers, only, at just a few major airports during early 2000 (e.g., Ottawa, Atlanta, San Francisco and Los Angeles), wireless connectivity is now available from WISP companies such as Wayport, iPass, and Boingo in many of the airports, hotels, and convention centers across the United States where business travelers congregate.^{88,89,90} Whereas only four major airports were initially covered in early 2000,

⁸⁶ Sturdevant, Cameron, *AirMagnet 1.2 reveals WLAN trouble spots*, eWeek, Ziff-Davis Publishing, May 6, 2002, pp. 48-50.

⁸⁷ Shaw, Russell. *More Web Users Look to WISP*. Investor's Business Daily, Monday, June 24, 2002, p. A6, Internet & Technology.

⁸⁸ <http://www.wayport.com/>

⁸⁹ <http://www.ipass.com/main.php>

today there are several thousand locations with Wi-Fi service available.⁹¹ Rates for services are still expensive, compared to flat rate dial-up or 24/7 DSL/Cable pricing. For example, in North America, using the iPass network through WorldHook costs \$5.00 per hour, plus an annual billing of \$24.95 to cover account maintenance.⁹² Considering that the typical traveling business user uses from 30 to 50 hours of Internet access per month, the cost for Wi-Fi at commercial rates is still considerably more than the cost for a functionally equivalent company dial-up on an 800 number dial-up to a VPN (Virtual Private Network). For many small companies, Wi-Fi public access service has been priced out of the range where the value is worth the expense.

The cost/benefit ratio, though, is changing weekly, improving especially with the introduction of the Wi-Fi service provided by Boingo that debuted in Spring 2002. Established by Internet Service Provider (ISP) Earthlink's chairman, Sky Dayton, Boingo is purchasing nationwide Internet access from Earthlink, and is re-selling this Internet access to roaming wireless customers. Pricing options range from Boingo Pro® priced at \$24.95 for ten connect days usage per month with unlimited access in single Boingo locations to Boingo Unlimited® which provides unlimited monthly usage for \$74.95 per month. For customers who are uncertain of their usage, Boingo As-You-Go® provides service at \$7.95 per day for unlimited access in single Boingo locations for up to 24-hours. Within the span of just a few weeks, Boingo locations have appeared at numerous sites throughout the country. For example, in Brevard County, FL, home of Kennedy Space Center, there were no public Wi-Fi services as of mid-2002. Within the span of just a few weeks in late spring 2002, two local hotels in Cocoa Beach and Melbourne⁹³ added Boingo service with lobby access for travelers to the Space Coast. Across Florida, twenty-six cities likewise now have Boingo locations (as of June 2002). Boingo also has made available free software to enable Wi-Fi equipped laptop users to know when they are within range of high-speed wireless Ethernet signals; both for free services as well as for premium pay-for-Ethernet services such as Boingo.⁹⁴

In contrast to Boingo's service aimed at business travelers, many universities are installing Wi-Fi networks to provide students with wireless Internet access on their now-required laptops in libraries, classrooms, and laboratories. The result has been to make

⁹⁰ <http://www.boingo.com/whatisboingo.html>

⁹¹ Consistent with airport expectations for wireless access today, the Spaceports and Ranges of the future will need to include similar capability to attract technologically savvy customers.

⁹² <http://www.worldhook.com/pricing.shtml>

⁹³

http://www.boingo.com/search.html?COUNTRY=1&METRO_SEARCH=on&CITY=136&CATEGORY=0&STATE=10&SUBMIT=Show+Locations

⁹⁴ <http://www.boingo.com/whatisboingo.html>

Wi-Fi adaptor cards a hot ‘back-to-school’ item on many students’ lists.⁹⁵ Other universities, planning ahead, now require new students (commencing Fall 2002) to come equipped with laptops having both a built-in 10/100BaseT wired Ethernet connection and a spare PCMCIA slot to permit installing future Wi-Fi cards at varying data rates to allow easy options for accommodating Wi-Fi technology upgrades.⁹⁶

Undoubtedly, the expansion beyond the first few thousand “hotspot” Wi-Fi locations will continue. According to some market forecasts, it is likely that relatively inexpensive Wi-Fi service will be available in almost all inhabited areas of the United States by 2005.⁹⁷ Connectivity for some of these areas will be made through the efforts of the high-priced companies that exist today, along with any new ISP companies that enter this business. The Spaceport and Ranges of the future will need such service to remain attractive to the traveling public.

Private individuals, instead of companies, may also serve many of these “hotspot” areas. For example, one start-up named Joltage provides software to enable operators of private home and business Wi-Fi networks to sell their spare Wi-Fi capacity to any passerby with a need to be Wi-Fi connected.⁹⁸ Based on a free software download that permits private Wi-Fi base operators to set up micro-ISP (Internet Service Provider)-controlled access to their private Wi-Fi network, private individuals can now benefit from providing Internet connectivity to the Joltage subscribers who pay \$1.99 per hour (\$24.99/month) for connectivity when within range of a participating private Wi-Fi network. At a fraction of the present commercial Wi-Fi rate charged across most of North America, this pricing rate seems destined to lure budget-conscious traveling subscribers. In turn, payment from Joltage is made once a month to each of the participating micro-ISP base owners scaled in accordance to the amount of traffic that has passed through each of their network(s). This payment is made electronically through the online PayPal™ service, an electronic payment service originally started to provide easy payment by credit card for Internet auction items sold on Ebay™.⁹⁹ Much like the increase in network congestion seen from Napster use during 2000 until 2001, which resulted in the banning of Napster

⁹⁵ http://www.wirelessethernet.org/pr/pr_pdf/Wi-Fi_Fall_01_Briefing.pdf

⁹⁶ Agnes Scott, a small liberal arts college in Atlanta, GA, for example, requires both a wired Ethernet capability as well as a spare PCMCIA slot in student’s laptops for providing future Wi-Fi upgrade options for all freshmen starting in the fall of 2002. Wi-Fi is still too new, and the fear of selecting the *wrong* Wi-Fi standard is still strong among university computer network administrators, hence the need for an empty PCMCIA slot.

⁹⁷ In contrast, 3G Wireless rollouts are not likely to occur before Wi-Fi guerrilla wireless achieves nearly total market saturation. This does not bode well for 3G Wireless service providers.

⁹⁸ <http://www.joltage.com/jsp/home/home.jsp>

⁹⁹ Although Joltage only publicly announced its *Joltage Provider Program*™ service and free download software on March 22, 2002, considerable interest was generated within just few days in the general Internet community regarding its fledgling Wi-Fi micro-ISP service.

and all other peer-to-peer sharing software programs on many college campuses, a similar recurrence is likely whereby existing broadband 24/7 ISPs ban entirely the re-selling of even small amounts of wireless bandwidth connectivity through DSL and cable modems owned by private citizens. The result may be that most home users may be barred by their own ISPs from becoming micro-ISPs. Assuming civil disobedience against this rule, however, it is highly likely that by 2005 or 2006, if not before, wireless Internet access will be available at relatively low cost through privately-owned Wi-Fi portals in most inhabited locations in North America.

An additional trend arose in June 2002; the fad of “warchalking” suddenly sprouted and spread throughout the high-tech geek world. Warchalking is an underground low-tech Wireless Ethernet fad that started in London for marking Wireless (i.e., ‘War-less’) Ethernet hotspots by chalk marks on sidewalks. These marks for digital hobos are analogous to the hobo codes used in America in the 1930’s to indicate information regarding dogs, food handouts, and other items of interest to hobos. Warchalking spread across high-tech geek hangouts within a matter of days to various locations in California, New York City, and other high-tech hotbeds around the world. Warchalking itself is a wordplay on “War-less”¹⁰⁰ Ethernet and ‘wardialing’, an earlier term made popular in the 1980’s in the movies, describing how computer users obtained surreptitious access to dial-up modem lines to gain Internet access through dialing through entire city telephone directories, in order to find modem lines. Through warchalking, users with high-speed Internet access mark the presence of Wireless Ethernet hotspots to share Internet access with others at no cost. Within a matter of only a few days, Time Warner Cable, owner of the RoadRunner® broadband Cable Modem service, issued cease and desist orders to users in New York City for sharing their broadband access upon publicly announcing their illegal Wi-Fi hotspots through warchalking.^{101,102,103,104}

An additional issue that may slow acceptance of even legally-operating public Wi-Fi portals is that none of the present public networks implemented to date has had any form of WEP installed and activated in order to keep the Wi-Fi publicly accessible.¹⁰⁵ Although a password is included, it is the word “Public” for most non-WEP, public systems. The threat is obvious, however. Anyone in a Starbucks or other similar Wi-Fi

¹⁰⁰ Warless is a word pun on “wireless”, pronounced with a dialect.

¹⁰¹ *A Wireless End Run Around ISPs*, Business Week Online, http://www.businessweek.com/technology/content/jul2002/tc2002073_1130.htm retrieved 15 July 2002.

¹⁰² Warchalking. <http://www.blackbeltjones.com/warchalking/>, retrieved 15 July 2002.

¹⁰³ Loney, Matt. *Want Wi-Fi? Learn the Secret Code*. C/Net News.com, <http://news.com.com/2100-1033-939546.html>, retrieved 15 July 2002.

¹⁰⁴ Boutin, Paul. *Wi-Fi Users: Chalk this way*. Wired News, 3 July 2002, <http://wired.com/news/wireless/0,1382,53638,00.html>, retrieved 15 July 2002.

¹⁰⁵ http://www.wirelessethernet.org/pr/pr_pdf/Wi-Fi_Fall_01_Briefing.pdf

equipped establishment using a Wi-Fi equipped laptop to access, say, her online brokerage account, could be exposing her portfolio to rather serious threats, unless her brokerage account was set up with both VPN (Virtual Private Network) and SSL (Secure Socket Layer) protection. (Adding VPN security is being addressed in the pay-for-Wi-Fi marketplace. Boingo, for example, is initialing bundling a Personal VPN Service for free both to provide their Wi-Fi users with security and to encourage early adopters to sign up for their Boingo service.¹⁰⁶) As for SSL, many of the smaller online brokerage houses are still operating with only 40-bit SSL protection, which is better than no protection, but does not provide much protection relative to even 128-bit key SSL protection. Adding a VPN connection to 40-bit SSL protection does result in a minimal acceptable level of protection. In most cases at present, private citizens, though, only have the minimal 40-bit SSL protection, especially if they travel internationally with their laptop.¹⁰⁷

Relative to Advanced Spaceport and Range use, the Ethernet-connected distances achievable with normal Wi-Fi would generally be too short to be of much use, certainly less than 600 meters. With small, inefficient, omni-directional antennas, especially within laptop cases inside lossy hotel buildings with metallic facades, this is certainly true. Yet, there are practical results reported publicly in which Ethernet-like speeds were achieved over a 5-mile wide valley, and plans are afoot for a 21-mile distance using stock Wi-Fi equipment.¹⁰⁸ Since present FCC rules govern only the maximum output RF power permitted from 802.11b equipment, and do not prevent the use of external high-gain antennas, or of restricting the maximum data rate on stock Wi-Fi equipments, the basic technique used is to employ directional antennas on both ends of the Wi-Fi link and slow down the transfer speed to extend the range.¹⁰⁹ A separate, yet similar approach has also been reported operating up to 14 km, with anecdotal evidence of 57 km ranges for Wi-Fi as being possible.¹¹⁰ All of these ranges are entirely consistent within the link budget capabilities of augmented, existing commercial Wi-Fi equipment, and the conclusion is obvious. It is now (as of May 2002) possible to extend the range of commercial Wi-Fi equipment to distances of tens of miles with commercially available equipment. A Wireless Building-to-Building Bridge such as the National Datacomm Corporation's NWH6110, promises 802.11b compatible coverage at 11 Mb/s rates over distances up to 18 miles (30km).¹¹¹

¹⁰⁶ <http://www.boingo.com/whatdoesitcost.html> The normal price for Boingo's Personal VPN Service software is \$30.

¹⁰⁷ The exportation of 128-bit Web Browser software outside of the United States is of questionable legality at present due to US State Department requirements, although many travelers (and some customs agents) ignore this.

¹⁰⁸ <http://www.oreillynet.com/pub/a/wireless/2001/05/03/longshot.html>

¹⁰⁹ This is not as far-fetched as it sounds. Similar experiments were done over similar distances during the mid to late 1980's at Harris Corporation (now Intersil) in Palm Bay, Florida with early discrete hardware implementations of what became the Prism™ chipset. Data rates in terms of Mb/s were achieved.

¹¹⁰ <http://macintouch.com/airportantenna.html>

¹¹¹ <http://www.ndc.com.tw/products/nwh6110.htm>

Extending Wi-Fi service to citywide WANs and providing the final mile of high-speed Internet connectivity to the SOHO (Small Office, Home Office) environment is also underway by at least one private company, Etherlinx Communications, Inc. of Cupertino, CA.¹¹² Etherlinx has a prototype product nearing the end of a one year field trial in Oakland, CA and Campbell, CA (as of June 2002).¹¹³ The basic approach that Etherlinx is using is to modify standard Wireless Ethernet Access Point bridges to create what they term a Consumer Premise Equipment (CPE) unit costing less than \$100. EtherLinx does this by re-using standard 802.11b equipment and then loading modified firmware that they call Smart Spectrum™. With their Smart Spectrum™ software, Etherlinx takes inexpensive 802.11b hardware and increases the functionality by running one side of the CPE normally, providing normal 802.11b operation throughout a home or business at adaptive rates up to 11 Mb/s. The other side of the CPE is re-configured within Smart Spectrum™ to operate at a rate of no more than 2 Mb/s, thereby extending the distance over which the upstream side of the equipment can operate. With high gain antennas and with the maximum data rate intentionally kept low, the radio link margin necessary for extending the range of the CPE relative to normal WEAPs is accomplished.

With their very economical technology re-use approach, Etherlinx has operationally “lit up” the South Bay and Oakland, CA areas with 2MB Ethernet.¹¹⁴ With a data rate of 2 Mb/s, very similar performance is achieved in practice by Etherlinx users relative to data rates usually experienced by Cable Modem users. Although Cable Modem users theoretically achieve a peak data transfer rate of 10 Mb/s on downloads, in practice, with many users connected, the typical rate is actually closer to 2 to 3 Mb/s. The typical monthly price of \$39.95 paid by many Cable Modem users will no doubt encourage many of these same Cable Modem users to switch to a lower cost Etherlinx model once field trials are completed and wireless service expands. The likely outcome will be a further industry consolidation of Cable TV companies and DSL companies, once significant numbers of their currently-subscribed customers start to abandon wired broadband services for lower cost, wireless services. Considering that some mergers in the last two years have resulted in evaluations and prices of as much as \$3,000 per customer that was paid to acquire an existing subscription base, any significant loss of customers switching to broadband wireless services will have dire consequences in terms of reduced cash flow for existing telephone and cable TV companies with DSL and Cable Modem revenues.

¹¹² <http://www.etherlinx.com/index.htm>

¹¹³ Markoff, John. *2 Tinkerers Say They've Found a Cheap Way to Broadband*. NY Times, 6 June 2002, <http://www.nytimes.com/auth/login?URI=http://www.nytimes.com/2002/06/10/technology/10WIRE.html> retrieved 17 June 2002.

¹¹⁴ <http://www.etherlinx.com/about.htm>

Still, it is not wise to think that *both* DSL and Cable Modem services are ‘out for the count’ when it comes to adding wireless convenience. Although, due to total bi-directional throughput limitations of around 1 Mb/s DSL services are largely confined to providing single user computers within SOHO setups with high speed Internet connectivity, Cable Modem users can experience higher speed download rates up to 10 Mb/s and typically have the bandwidth needed to simultaneously support multiple users. As a result, Cable Modem subscribers have been adding Wi-Fi routers and WEAPs to their SOHO setups to share high-speed access throughout their LAN to multiple computers. In their quest to win market share at the expense of DSL ISPs, this differentiator in download bandwidth advantage for Cable Modem users has not gone unnoticed by Cable Modem ISPs. Cable providers are now proactively addressing the future threat of WISPs (Wireless Internet Service Providers), as well as competition from existing DSL ISPs, through planning built-in wireless networking additions to Cable Modems/cable set-top boxes. Further, they plan to transmit video simultaneously to other TVs, as well as to handle Internet traffic, using the same technology. Wireless chipmakers such as startup Magis Networks of San Diego, CA, are developing chips to provide video, data, and even audio content over Wireless Ethernet (Wi-Fi). Both Broadcom and Intersil are likewise investigating this emerging market, to leverage technology from their DOCSIS and Wi-Fi chip designs, respectively.^{115,116}

With the introduction of such new Wi-Fi devices, services, and startup companies, the reason for focusing on Wireless Ethernet becomes obvious. Wi-Fi is already winning the lion’s share of the existing and emerging markets. Competing 3G Wireless services, being slow out of the gate, and with spectrum auctions not even planned in the US until September 2002, are already losing the market share race to Wireless Ethernet before the real race even starts. To make matters worse, planned 3G Wireless data transfer performance is much worse than *existing* Wireless Ethernet as demonstrated in field trials! Wireless Ethernet is rapidly becoming the clear winner in terms of market acceptance, infrastructure cost, and technology availability.

Long-distance Wireless Ethernet technology would be of great benefit for installing a WAN around future Spaceports dispersed over large geographic areas. Obviously, such a Spaceport and Range WAN would need a more secure WEP than is presently available to

¹¹⁵Mowrey, Mark. *Coming soon to your cable box: built-in wireless networking*. Red Herring, July 2002, p. 23.

¹¹⁶ Magis Networks raised \$40 million in second round VC funding in April 2002 from a pool of investors that includes AOL Time Warner (owner of Time Warner Cable and the RoadRunner® broadband Cable Modem service), Motorola, and Vulcan Ventures. Vulcan Ventures, a VC company, is run by Paul Allen, who is also the chairman of Charter Communications. Charter Communications and AOL Time Warner together serve more than 25% of US cable TV subscribers. Through funding wireless chip developments, both Charter Communications and AOL Time Warner are laying the necessary chip support infrastructure to support the wireless distribution of video, data, and audio content over Wireless Ethernet within the SOHO environment to their cable subscribers. This transition will likely be the final nail in the coffin for DSL, which has been slow to be fielded, and has been over-hyped for many years.

prevent wireless intruders from gaining access. Such solutions may be available by 2003. Nonetheless, once WEP security is improved, it would be possible to integrate numerous Spaceport and Range web pages and control interfaces and to make them remotely and securely accessible through a laptop with (at most) an external directional antenna being needed at the greatest ranges desired. Wi-Fi distance-extending hardware antenna kits with 14 dBi gains are commercially available now (May 2002), eliminating the expense of digging miles of trench to lay Ethernet cables.¹¹⁷ Such disruptive Wi-Fi technology significantly reduces the cost of providing reliable, Ethernet-speed connectivity over both WAN and LAN distances for Spaceports and Ranges of the near future.

For the foreseeable future however, only 802.11b will likely be used in connecting Spaceports and Ranges. The communication ranges possible with 802.11a and 802.11g hardware simply will not support the expanses planned for the Spaceports and Ranges that are being considered. This will not change, either, since commercially produced 802.11a and 802.11g hardware must be built in accordance with existing IEEE 801.11a standards and this hardware will **NOT** be good enough in terms of link budget performance to cover the distance expanses planned for Spaceports and Ranges. If anything, it may be prudent to stockpile 802.11b hardware capable of operating over the distances required in order to maintain basic Spaceport Ethernet-speed wireless communication capability far into the future. Alternatively, it would be possible to commission the design of special 802.11a/g hardware having improved receiver sensitivity performance and higher gain phased array antennas, while simultaneously petitioning the FCC to permit its use. The likelihood of this happening is rather low, due to protection requirements necessary to achieve non-interference with other communication links operating on adjacent frequencies to the approved frequencies for Wi-Fi.

The more cost-effective and likely solution, therefore, would be just to stockpile 802.11b equipment, as the data throughput capability of this equipment would likely meet the basic Ethernet needs though at least the first ten years of operation for future Spaceports and Ranges. Although Spaceport users might complain of the ‘slow’ throughput of only 11 Mb/s in the future, it would certainly be better than no service. Within Spaceport Terminals, though, faster, shorter range, wireless Ethernet equipment could be installed. The use of wireless laptops while sitting inside trans-Atmospheric vehicles, awaiting final clearance for gate rollout, could be based on long-range 11 Mb/s data rate equipment.

4.2.2 Bluetooth

Besides Wireless Ethernet, it should be mentioned that there is one other short-range wireless technology that is also often mentioned as a possible replacement for cables over very short distances -- roughly 30 feet or less. This shorter-range technology, dubbed

¹¹⁷ <http://www.ndc.com.tw/products/nwa0214.htm>

Bluetooth, is named in honor of the 10th Century King Harold Bluetooth who united various tribes of Vikings that had formerly not worked together. Bluetooth is slower than Wi-Fi and is capable of data transfer rates of only about 1 Mb/s.¹¹⁸ Whereas Wi-Fi is a WLAN (Wireless Local Area Network) technology, Bluetooth is instead a WPAN (Wireless Personal Area Network). Bluetooth is therefore primarily designed to link a cell phone to a laptop, or a Personal Digital Assistant (PDA) to a cell phone, or a laptop to a printer, or projector – all without cables.

Bluetooth, also known as IEEE 802.15.1, is not a serious threat to Wi-Fi, even though Bluetooth's power consumption is less than Wi-Fi.¹¹⁹ Some pundits claim that 802.11b has already won the competition.¹²⁰ The reason is that Bluetooth data rates and operational ranges are simply too small relative to Wi-Fi, and Wi-Fi peripherals for the WPAN market envisioned for Bluetooth are already starting to appear. For example in November 2001 at COMDEX in Las Vegas, Linksys announced the introduction of a Wireless Ethernet print server, intended for putting printers onto Wi-Fi networks.¹²¹ As of May 2002, these Wi-Fi print servers are available nationwide at a retail cost of around \$125.¹²² In volume, the prices for such print servers quickly drop below Bluetooth equivalent link equipments.

In addition, at the same COMDEX show, Linksys announced an Instant Wireless Presentation Gateway (WPG11) to enable multiple Wi-Fi equipped PCs to control a presentation or projector screen from the user's keyboard. Serving WPAN functions in corporate meetings, conferences, or interactive training sessions, the Presentation Gateway provides a solution for a use that Bluetooth has yet to address. The Instant Wireless Presentation Gateway from Linksys has an estimated retail price of \$299.

From these examples, it is obvious that Bluetooth is losing market share for the very WPAN market for which it was developed, and Wi-Fi is already dominant in this market. If Wi-Fi adaptor cards and peripherals continue to drop in price, which is likely to occur as production volume ramps, Bluetooth will clearly have cost competitiveness problems relative to 802.11b. If the Bluetooth protocol survives, it will become a niche wireless connection technology with limited applicability on just the very fringe of the communication networks of the future.

Relative to its possible use on the Spaceports and Ranges of the future, Bluetooth will likely be used, if at all, just to connect personal items (cell phone, PDA, laptop, printer) within just one office, or within single buildings, or between crew members and

¹¹⁸ Bluetooth typically provides operation only up to 10 meters at maximum data rates up to 721 kb/s.

¹¹⁹ Pete Fowler. *5 GHz Goes the Distance for Home Networking*. IEEE Microwave Magazine, September 2002, p. 53.

¹²⁰ http://www.mobilian.com/documents/WinHEC_whitepaper.pdf

¹²¹ http://www.80211-planet.com/news/article/0.4000.1481_922001.00.html

¹²² Linksys' Wireless Print Server is termed a WPS11.

passengers and their luggage in the WPAN mode. A more likely outcome is that Bluetooth will be abandoned for a mix of Wi-Fi technology for higher data rates and longer distance applications and Zigbee technology (to be discussed later) for lower-cost, lower-data rates and, especially, for battery-powered applications. Together, Wi-Fi and Zigbee will likely squeeze Bluetooth completely out of the marketplace. As such, Bluetooth hardly warrants more than a passing mention. Its impact on future Spaceports and Ranges will likely be minimal.

4.2.3 3G Wireless

As introduced earlier, 3G (3rd Generation) Wireless services are intended to provide a wide range of telecommunication services in support of both fixed and mobile users worldwide. In addition, the hardware for 3G Wireless services will encompass a wide range of mobile terminal types linked to terrestrial and/or satellite-based networks, and the terminals will be designed for mobile or fixed use. To date, the overarching emphasis of 3G Wireless systems is an inordinate focus on seamless billing and collection of roaming charges from users while providing worldwide service connections. This emphasis is to be achieved through a high degree of commonality of designs worldwide, compatibility of international services, and the use of small pocket terminals with worldwide roaming capability. Further, unlike the majority of 2G Wireless Cell phone services seen today, 3G Wireless systems will support multimedia applications and provide interfaces to the Internet and a wide range of other services and terminals. According to the International Telecommunication Union (ITU) International Mobile Telecommunications 2000 initiative ("IMT-2000"), numerous 3G Wireless system services were scheduled for initial introduction in 2000, subject to market considerations.¹²³ Only one field trial actually occurred in 2000, in October 2000 in the Republic of Korea.¹²⁴ 3G Wireless companies in Europe were licensed in 2000, and paid dearly for their licenses. However, with the worldwide slowdown in Telecommunications that commenced in March 2000, they have not achieved any semblance of breaking even on their license fees even, as of late 2002, nor have more than very limited field trials been conducted. The result has been relatively few functioning hardware demonstrations, and no significant service capabilities having been made available to significant numbers of customers in multiple countries.¹²⁵

¹²³ The Ultimate IMT-2000 Gateway on the World Wide Web, <http://www.imt-2000.org/portal/index.asp>, retrieved June 10, 2002.

¹²⁴ SK Telecom conducted the very first CDMA2000 1X field trial in October 2000. See: http://www.itu.int/osg/imt-project/Subdirectories_links/implementation.html. (Retrieved June 10, 2002.)

¹²⁵ Only seven very limited CDMA2000 tests have occurred only in the Republic of Korea, Canada, Japan and the US from 2000 through April 2002. None have occurred over April 2002 through June 2002. (CDMA2000 governs the 800/900/1800/1900 MHz bands.) From 2000 through January 2002, limited W-CDMA tests have only occurred in Japan, Norway, Finland, Sweden, France, Italy, the Isle of Man, and Monaco. (W-CDMA 1885-2025 MHz, 2110-2200 MHz.) Since January 2002 through June 2002, no additional W-CDMA tests have occurred, due to the telecommunications market downturn and a lack of funding. The major technical problem causing the delay of 3G field trials has been a serious lack of

That 3G Wireless systems have been slow to enter the mainstream is due to several factors. First, 3G Wireless systems are not usually configured in WANs, nor do they support Ethernet, which is rapidly taking over the networked planet. Second, whereas Wi-Fi provides data rates ranging from 11 Mb/s up through 54 Mb/s, and even higher rates are planned for the future, 3G Wireless provides a much more limited and now dated capability to support circuit and packet data at significantly lower bit rates ranging over:

- 144 kilobits/second or higher in high mobility (vehicular) traffic
- 384 kilobits/second for pedestrian traffic
- 2 Megabits/second or higher for indoor traffic

To date, 3G Wireless’s primary focus appears to have been on billing users and not missing any charges, rather than on improving technical performance. For example, interoperability and roaming are established whereby service providers share common billing/user profiles through:

- Sharing of usage/rate information between service providers
- Standardized call detail recording
- Standardized user profiles

Likewise, capability to determine geographic position of mobiles and to report location data to both the network and the mobile terminal are provided.

However, when it comes to performance, 3G Wireless is falling further behind Wi-Fi. When 3G Wireless was first investigated, the technical attributes deemed feasible were considerably less than what has become possible in the last eighteen months. Bluetooth, for example, was planned only for supporting data rates up to 1 Mb/s, or so, and the thought at the time was that providing data rates of 2 Mb/s for 3G Wireless would be more than enough bandwidth to support all possible future needs. As a result, the planned 3G Wireless network vision of multimedia services/capabilities is flexible although no longer truly broadband, with limited features such as:

- Fixed and variable rate bit traffic
- Bandwidth on demand
- Asymmetric data rates in the forward and reverse links
- Multimedia mail store and forward
- “Broadband” access up to 2 Mb/second

handsets. See: http://www.itu.int/osg/imt-project/Subdirectories_links/implementation.html (Retrieved June 10, 2002.)

The development cycle for 3G Wireless has also been inordinately long, relative to commercial development cycles that are producing competing Wi-Fi products, with the result that the performance of 3G Wireless is rapidly being surpassed by newer, unlicensed services, such as Wi-Fi. *“On October 13, 2000, the President executed a memorandum that articulated the need to select radio frequency spectrum to satisfy the United States' future needs for mobile voice, high-speed data, and Internet-accessible wireless capability. The Presidential Memorandum established for the Executive Agencies guiding principles to be used in selecting spectrum that could be made available for 3G wireless systems, and strongly encouraged independent federal agencies to follow the same principles in any actions they take related to the development of 3G systems.*

Noting the joint spectrum management responsibilities of the Executive Branch and the Commission, the Presidential Memorandum directed the Secretary of Commerce to work cooperatively with the FCC: (1) to develop a plan to select spectrum for third generation wireless systems by October 20, 2000; and (2) to issue by November 15, 2000 an interim report on the current spectrum uses and potential for reallocation or sharing of the bands identified at the 2000 World Radiocommunication Conference that could be used for 3G systems. These actions were taken to enable the Commission to identify spectrum for 3G systems by July 2001 and auction licenses by September 30, 2002.

In accordance with the Presidential Memorandum, the Department of Commerce released a "Plan to Select Spectrum for Third Generation (3G) Wireless Systems in the United States" (Study Plan) on October 20, 2000. The Study Plan noted that although various frequency bands have been identified for possible 3G use, the Commission and the National Telecommunications and Information Administration (NTIA) needed to undertake studies of the 2500-2690 MHz and the 1755-1850 MHz frequency bands in order to provide a full understanding of all the spectrum options available. The Study Plan called for the Commission to complete an Interim Report on the 2500-2690 MHz band and for NTIA to complete an Interim Report on the 1755-1850 MHz band by November 15, 2000.

In March 2001, the Commission issued a Final Report on the 2500-2690 MHz band and NTIA issued a Final Report on the 1755-1850 MHz band. The NTIA Final Report also addressed the 1710-1755 MHz Federal Government band. Comments were received on these reports in April 2001. In July 2001, FCC Chairman Powell and Commerce Secretary Evans exchanged letters, in which they agreed to postpone the July 2001 deadline for the Commission to identify spectrum for 3G systems. Secretary Evans informed Chairman Powell that he has directed the Acting Administrator of NTIA to work with the FCC to develop a new plan for the selection of 3G spectrum, to be executed as quickly as possible.

In September 2001, the Commission added a mobile allocation to the 2500-2690 MHz band to provide additional near-term and long-term flexibility for use of this spectrum, thereby making this band potentially available for advanced mobile and fixed terrestrial wireless services, including 3G and future generations of wireless systems. However,

*because the 2500-2690 MHz band is extensively used by incumbent Instructional Television Fixed Service and Multichannel Multipoint Distribution Services licensees, and in order to preserve the viability of the incumbent services, the Commission did not relocate the existing licensees or otherwise modify their licenses.”*¹²⁶

The result has largely been that 3G Wireless specifications in the United States reflect a wireless system designed by committee that unfortunately has become mired in the performance limitations that existed at the time the committee commenced work. Meanwhile, IEEE 802.11b largely grew out of the efforts of one company, Intersil (formerly Harris Corporation, Semiconductor Division), and a small number of associated companies. The result has been that Wi-Fi has made a much more rapid and intensified effort to encompass technological changes, sooner, providing much more quickly increasing performance.

3G Wireless has largely fallen behind the existing Wi-Fi technology, and the situation for 3G Wireless is actually worse than even the present situation would indicate. UWB (Ultra Wideband) technology, as discussed later, is on the verge of reconstituting the basic RF (Radio Frequency) technology used for Wi-Fi connections. With UWB, data compression is largely rendered obsolete. UWB can also meet much stronger security protection than even 3G Wireless can meet, while simultaneously extending battery life for portable wireless systems into the hundreds of hours without requiring any change from the battery technologies of today. 3G Wireless seems doomed both to miss the market of today, as well as to see its demise hastened further once UWB systems are fielded.

For these reasons, 3G Wireless systems are not expected to play any significant data-handling role in the Spaceports and Ranges of the future. They will simply provide too little, too late, at too much cost.¹²⁷ The only likely exception for 3G Wireless Systems is for providing international cell phone service, much as provided by the GSM (Global System for Mobile communication) services of today in Europe, and in some parts of the US.¹²⁸ However, GSM is the *de facto* wireless telephone standard in Europe today, and boasts over 120 million users worldwide in 120 countries. The GSM service may therefore prevent the expansion of 3G Wireless for cell phone service. If this is the case, 3G Wireless Services will have no significant market remaining. Cell phones, with the numbers of units already fielded, provide a significant hurdle to being replaced by newer, more costly, and not significantly more capable, 3G cell phones. The result is not going to be pretty, either, for shareholders of 3G Wireless licensed companies, as the impact of

¹²⁶ Federal Communications Commission, <http://www.fcc.gov/3G/>, retrieved June 6, 2002.

¹²⁷ Perhaps 3G Wireless should become *3Too* Wireless, instead.

¹²⁸ The US GSM system operates in an incompatible and different frequency range than that used in Europe. A US GSM phone does not automatically provide service across Europe and the parts of the US where GSM is available, unless the GSM phone happens to be a multi-band GSM phone, intended for use in *both* Europe and the US.

companies having bid so high for 3G Wireless licenses hits home further, causing new bankruptcies. Rather than 3G Wireless, it is likely that Wireless Ethernet services will meet the bulk of the communication network needs on future Spaceports and Ranges.

4.2.4 Zigbee

The mantras of smaller, cheaper, and lower-power operation relative to existing wireless technologies are presently best exemplified by the IEEE 802.15.4 WPAN (Wireless Personal Area Network) standard. This standard is presently undergoing finalization of technical specification development for physical and media-access control layers. Known as Zigbee, this WPAN technology promises to reduce recurring hardware costs to less than \$2 per communication node when implemented into systems.¹²⁹ To accomplish its smaller, cheaper, and lower-power operation attributes, the trade made is reduced data-rates. The expected result is power consumption low enough to permit battery operation for services ranging from months to years, thereby permitting the introduction of wireless technology into areas that previously made no sense. Zigbee holds considerable promise for becoming the very low-cost, low-power consumption two-way, wireless communications standard for industrial and home automation use in diverse applications including agricultural crop sprinklers, thermostats, factory floor automation, wireless-enhanced toys, & PC peripherals. The third round of balloting for the Zigbee draft specification is scheduled for conclusion by the end of August 2002. After this, vendors plan to finalize system specifications by October 2002, and samples are planned of one-chip Zigbee solutions by March 2003.^{130,131}

Zigbee originated as a “Lite” offshoot of the Philips’ HomeRF specification, based on additional specification contributions from Motorola. The Zigbee Alliance was formed quietly in early 2001, comprised of leadership from Philips, Honeywell and Invensys Metering Systems, among others. The top Zigbee Alliance goal was to address the disappointment that Bluetooth had largely become, especially in terms of achieving affordable performance. Like Wi-Fi, Zigbee is another Part 15 unlicensed wireless technology operating in the 2.4 GHz ISM band. Zigbee offers a data rate of less than 220 kb/s at distances up to 75 meters. (Bluetooth, in contrast, provides operation only up to 10 meters at data rates up to 721 kb/s.) As discussed earlier, Wi-Fi has already largely captured the high data-rate WPAN market that was intended for Bluetooth. Wi-Fi, though, is truly overkill for many wireless communications needs. It is a relatively expensive high-end solution. Zigbee, on the other hand, is intended to address the cost issues through fundamentally reducing the data rate and reducing (slightly) the maximum

¹²⁹ Zigbee is the current preferred generic name for IEEE 802.15.4 standardized technology. Earlier proprietary names for the same technology included PURLnet, RF-Lite, Firefly, and HomeRF Lite.

¹³⁰ *Wireless spec stands out in crowd.* EE Times. August 5, 2002, pp. 2, 10.

¹³¹ Palowireless Zigbee Resource Center, <http://203.147.194.107/zigbee/resources.asp>, retrieved August 7, 2002, representing the Zigbee Working Group.

distance over which two-way wireless connectivity is provided. At 2002 prices, complete Wi-Fi systems retail for around \$150 for a pair of PCMCIA form-factor Wi-Fi cards intended for interconnecting, for example, two laptops in an *ad hoc* mode of operation. In this mode of operation, Wi-Fi provides 11 Mb/s connectivity over distances up to as much as 1800 feet outdoors. For users requiring this high data rate, and long communication distance, Wi-Fi is a good solution.

Zigbee system prices are aiming at a different market, with a planned recurring cost of only \$2 to \$4 per system pair. For many applications, providing data rates up to 220 kb/s at distances up to 75 meters for less than \$5 per system pair opens up an entirely new set of applications. Zigbee further allows up to 250 nodes per network, thereby permitting a higher density of nodes per network than Wi-Fi. Much as cell-phone networks have gone to micro-cells to increase their capability to handle more nodes per network, Zigbee promises to address similar density issues within the 2.4 GHz ISM band currently shared among Zigbee, Wi-Fi, Bluetooth, and other services.¹³²

Another fundamental difference with Zigbee is that there are no intellectual property issues such as exist with Bluetooth. The Zigbee Alliance specifically structured the Zigbee specification to make Zigbee an open standard. The Zigbee Alliance is, at heart, an alliance of chip companies that simply wish to concentrate on selling very large numbers of single-chip Zigbee solutions; in contrast to the Bluetooth consortium formed by system provider companies wishing to sell high-priced systems with wireless convenience capability. Much like the proverbial saying that a horse designed by a committee becomes a camel, having too many participants often results in trying to meet too many disparate needs in a new technology such that a technology developed by a committee often meets no user's need well. Bluetooth, which started with great fanfare, has become a technological misfit solution that serves no specific need well. With fewer participants, fewer agendas that must be included in the Zigbee specification, and a streamlined specification that supports low-cost implementations in single-chip solutions, Zigbee appears positioned to become the dominant WPAN technology within the next five years.

Relative to its use on future Spaceports and Ranges, Zigbee could very well become the dominant technology used to provide WPAN connectivity for travelers using future Spaceports and Ranges. Zigbee could be used for automation of non-critical functions, such as walk-around thermostats (to be used much as a TV remote control) for controlling comfort zones within Spaceports. It could also be used for data linking applications among PDAs, cell phones, cameras, laptops, and other personal, body-worn, or hand-carried items. In the pervasively wireless future envisioned in this report, Zigbee is likely to serve a major role for non-critical function data linking for WPANs.

¹³² Yoshida, Junko. *Group backs Zigbee as a pervasive wireless spec*. EE Times, November 12, 2001, <http://www.eetimes.com/story/OEG20011112S0005> retrieved 7 August 2002.

4.3 FREE SPACE OPTICAL (FSO) COMMUNICATION SYSTEMS

In its simplest form, transmitting information by optical means through free space dates to pre-history. Signal fires on a mountaintop, or the mere absence or presence of a lit torch or lantern, likely were the earliest YES or NO digital modulation signaling techniques. Among the earliest recorded records of an optical signaling scheme are those attributed to Aeneas in 350 BC for sending alarm signals. This was followed by the torch signals used by Polybius in 150 BC to encode the 24 letters of the Greek alphabet, in the first recorded optical telegraph.¹³³ Nearly 1,900 years would pass before the famous “One if by land, two if by sea” lantern encoding was used in a church steeple in Boston on the evening of April 18, 1775.¹³⁴ Less than two decades after Paul Revere’s ride, optical signaling concepts had evolved into a formal Free Space Optical (FSO) communication system known as the optical telegraph. Invented in the early 1790s by French engineer Claude Chappe, who first coined the French word “*télégraphe*” to describe his system, the 18th Century optical telegraph used a series of semaphores mounted on towers manned by human operators to relay messages from tower to tower. From its inaugural network of May 1794, Chappe’s system eventually grew to 556 stations spanning 3,000 miles across France, Algeria, and Morocco. A mobile network was even built, and was used during the Crimean War.¹³⁵ Data throughput transfer rate was about 20 to 30 seconds per symbol.¹³⁶

Across the English Channel, the English soon had their own version of an optical telegraph up and running. In 1795, the Royal Navy decided to construct its own free space optical telegraph system to enable the Admiralty in Whitehall to communicate with the Portsmouth Naval Base on the south coast of England. At first, a shutter technique was used, but in 1822 the link was upgraded to a semaphore system, much as the French had done, to speed signaling rates. Messages could be sent over the 108 km path to Portsmouth in about fifteen minutes, which was greatly faster than sending the same information via horseback. This early optical information superhighway was in operation until about 1847, when the electric telegraph superseded it.¹³⁷ The French optical telegraph similarly became obsolete in 1855. Contributing to its 61-year longevity was its ability to resist sabotage; unlike the competing and more modern electrical telegraph, it had no wires that could be severed.¹³⁸

¹³³ http://www.ieee.org/organizations/history_center/cht_papers/dilhac.pdf

¹³⁴ <http://www.paulreverehouse.org/midnight.html>

¹³⁵ http://www.ieee.org/organizations/history_center/cht_papers/dilhac.pdf

¹³⁶ *ibid.*

¹³⁷ <http://www.ee.surrey.ac.uk/Personal/R.Clarke/sema4/>

¹³⁸ http://www.ieee.org/organizations/history_center/cht_papers/dilhac.pdf

Long after the obsolescence of the landlubber optical telegraph, the Navies of the world continued to use the earlier optical telegraph shutter technique employed by the British, using Morse code modulation of a shutter physically located in front of an electrically powered search light. When staffed with experienced operators, this simple manually operated free space optics communications system could achieve 10 to 15 WPM (words per minute) data transfer rates. Assuming a 5-character word with 8-bit character representation, a 15 WPM modulated light is about the equivalent of a data transfer rate of 100 bps. By enhancing visual ‘reception’ through using two operators on the receiving end, whereby one equipped with binoculars would call out alphanumeric characters to the second who would write down the message, it became possible to communicate over several miles between ships at sea. With hooded searchlights, some degree of directional privacy was even possible.

The next step in the development of free space optical communications systems was considerably more advanced. In 1880, after inventing the wired telephone, Alexander Graham Bell patented a free space optical telephone system, which he called the Photophone. Based on amplitude modulation of an incandescent light bulb, the Photophone was capable of sending voice over short distances in fixed, point-to-point applications. Unfortunately, it was not reliable, and the difficulty of connecting multiple parties to the communication line proved insurmountable, especially when compared to the ease of connecting wired telephones together into networks. The invention of low-loss optical fiber, which would have eased the implementation of Photophone technology greatly, would not occur until nearly a century later, in 1970. As for Bell’s optical communication system, his experimental Photophone was donated to the Smithsonian Institution, where it literally languished on the shelf for over half a century before light was once again used to transmit voice.¹³⁹ During World War II, all private amateur (ham) radio wireless transmissions were banned. In areas where black-out rules were not in effect, some hams in both the US and Britain experimented with AM modulation of search lights to communicate by voice over distances up to several miles. As soon as the war was over, though, this optical communication experimentation largely stopped, and free space optical communication experimentation became dormant once more.

After Bell’s Photophone, with the exception of the limited experimentation during World War II, the use of free space optics to transmit data was largely forgotten until 1960. The invention that changed everything, and which accelerated interest in FSO communication, was the laser. Invented in 1958 by Schawlow and Townes at Bell Labs who filed for a patent that year, the laser was an outgrowth of an earlier maser (**M**icrowave **A**mplification through the **S**timulated **E**mission of **R**adiation) device invented in 1953.¹⁴⁰ Adding mirrors, and increasing the frequency into the light region, the maser concept became a laser, and the possibility of generating narrowband coherent light became not only theoretically possible, but practical in fact. Such a light source

¹³⁹Hecht, Jeff, *City of Light: The Story of Fiber Optics*, Oxford University Press, New York 1999.

¹⁴⁰ <http://www.bell-labs.com/history/laser/>

could be modulated at very high data rates, and, due to beam coherence, be transmitted over large distances with minimal beam spreading. It was an obvious FSO light source waiting to be used. In 1960, Theodore Maiman at Hughes Aircraft Company built the first working laser. In addition, in 1960, the Bell Lab's patent on the laser, filed in 1958, was granted.¹⁴¹ In addition, in 1960, and because of this confirmation of the earlier theoretical laser research, forward-thinking government researchers started to pay particular attention to Free Space Optical (FSO) communication systems for transmitting data.

Although FSO interest was sparked in 1960 with the reduction to practice of the laser, and research projects and experiments were funded and continued throughout the 1960s, during the 1960s FSO communication systems remained mostly a laboratory curiosity, with relatively few specialized communications systems being deployed. This state of affairs largely continued until the breakthrough discovery of low-loss fiber optic cable manufacturing techniques by Robert Maurer, Donald Keck and Peter Schultz of Corning Glass Works (now Corning, Inc.). The goal, in terms of being able to reduce fiber optic communications to a position of competitiveness with coaxial cable systems, had long been to achieve a loss-limit of 20 dB/km, or less. Their breakthrough discovery that accomplished this was announced in September 1970, and it heralded the arrival of single-mode fiber (SMF) cable with attenuation below 20 dB/km at the 633-nanometer helium-neon line.

With this low-loss breakthrough, the progression of fiber-optic cable communications soon led to the development of ever increasingly sensitive photodetectors (PINs, APDs, MSMs, etc.) simultaneous to the development of more powerful light sources in the form of continuous output light sources based on laser diodes, Fabry-Perot lasers, Vertical Cavity Surface Emitting Lasers (VCSELS), and Distributed-Feedback (DFB) lasers, to take advantage of the new low loss SMF. Simultaneous to the development of short wavelength lasers at 850 nm wavelengths, the development of lasers at the commercially-significant wavelengths around 1310 nm and 1550 nm, where fiber dispersion and loss were less, were likewise developed. In addition, the introduction of Erbium Doped Fiber Amplifiers (ERDAs, or EDFAs) made the amplification of modulated laser light possible without the need for subsequent detection, conversion to electrical signals, and re-modulation of another laser, while simultaneously reducing the lens issues associated with traditional FSO systems.

Together, these developments over the thirty-year period starting in 1970 have provided all the building blocks required to go to the next step, in many cases entirely eliminating the need for fiber-optic cable for short-distance communications, and making FSO communications a commercial possibility. For example, the primary patent for Free Space Optics using EDFAs was only filed on April 24, 1998 and granted on May 29, 2001 to LightPointe Communications of San Diego, CA.¹⁴²

¹⁴¹ U.S. Patent #2,929,922

¹⁴² United States Patent 6,239,888 granted to LightPointe Communications, <http://www.lightpointe.com/>

EDFAs were originally developed as fiber optic cable link repeater amplifiers. Erbium doping of an optical fiber allows light amplification over a wavelength band of approximately 30 nm centered around a basic wavelength of 1550 nm. To operate at the wavelength whereby dispersion is tolerable and attenuation is the lowest, a wavelength of 1550 nm is usually employed in long-haul fiber-optic communication systems. By taking advantage of the natural wavelength at which Erbium atoms are most sensitive, EDFAs are particularly advantageous in extending the range over which 1550 nm fiber optic link systems can operate. Previously, the 1550 nm wavelength has not been regarded as important in free space optical communication networks because of high atmospheric attenuation and refraction at 1550 nm, employing higher powers of the 1550 nm optical signal can be used to counter the less effective characteristics of the 1550 nm wavelengths. The end result is that FSO systems have only become truly practical in terms of their reliability and cost-effectiveness, while providing fiber-optic cable competitive data rates of 2.5 Gb/s, within just the last two years.¹⁴³

Whereas a Wi-Fi (Wireless Ethernet) connection can provide 10 Mb/s through 54 Mb/s data transfer speeds over a wide, largely omni-directional area, an FSO connection can provide a choice of 10 Mb/s, 20 Mb/s, 100 Mb/s, 155 Mb/s, 622 Mb/s and 1.25 Gb/s at 850nm without EDFAs, and even higher rates of OC-48 2.5 Gb/s and OC-192 10 Gb/s data transfer speeds at 1550nm over long distances and narrow beam widths with EDFAs. FSO communication systems using EDFAs are therefore best suited for fixed, high data-rate backbone connections.

In addition to the fixed, high-capacity FSO links employing EDFAs that behave much the same as Intermediate Reach (IR) buried fiber-optic lines, there are also shorter-range, lower-cost FSO links available without EDFAs. One of the leaders in this technology is Terabeam, located in Kirkland, WA.¹⁴⁴ Through the use of their Elliptica Series of products, Fast Ethernet (100 Mb/s) and OC-3/STM1 (155 Mb/s) connectivity is available over short distances. Through the use of their Magna Series of products, both OC-12/STM-4 (622 Mb/s) and Gigabit Ethernet (1 Gb/s) protocols are available over short distances. In terms of responsiveness, Terabeam is the present leader in the industry for rapidly installing new communications links. For example, after the attack on the World Trade Center on September 11, 2001, Merrill Lynch, one of the world's leading financial management and advisory companies, was able to replace its damaged conventional links installed in the area around Ground Zero in only two weeks using Terabeam hardware. These likewise do not significantly overlap in terms of their data rates with Wi-Fi and Wi-Fi 5 technologies.

¹⁴³ http://www.lightreading.com/document.asp?site=lightreading&doc_id=6001

¹⁴⁴ <http://www.terabeam.com/>

In addition to terrestrial uses of FSO communication systems, it is also possible to use them in space. In many ways, FSO communication systems are better suited to space than on earth since there are no weather or other atmospheric impairment effects.¹⁴⁵ For example, the European Space Agency (ESA) Artemis satellite was built in Europe by a consortium of companies and launched 12 July 2001 from the European launch base in Kourou, French Guiana aboard an Ariane 5 launch vehicle.¹⁴⁶ Orbiting at 31,000 km altitude, it used a laser-based Silex Communication system to transmit 50 Mb/s to a SPOT 4 satellite at 832 km altitude on November 30, 2001 in the first-ever publicly announced satellite-to-satellite laser-communication link demonstration. A Bit Error Rate (BER) performance of 10^{-9} to 10^{-10} was demonstrated, which is only slightly worse than the error-rate seen in traditional earth-bound fiber-optic links which typically must meet BERs of 10^{-12} . From SPOT 4, a conventional 20 GHz microwave downlink was then used to downlink relayed earth images back to Toulouse, France. The immediate purpose was to provide a space-based relay capability demonstration to prove the feasibility of sending customer-requested data back to France in real-time when line of sight downlink look-angle geometries do not exist for any particular satellite. Although Artemis is a dual-purpose satellite built to demonstrate affordable, wide-coverage mobile communications satellite services and to test direct satellite-to-satellite communications, its revolutionary laser link shows the greatest promise for achieving truly secure space-based relay communication systems. Based on Artemis' success, it is likely that future ranges may very well need to include communication capabilities to interface with secure, space-based laser relay spacecraft used to implement critical parts of Space Based Range (SBR) Distributed Subsystems.^{147,148,149}

The conclusion for both terrestrial and space-based communication links, therefore, is that FSO communication systems clearly provide disruptive technology capability unavailable through any other means for the advanced Spaceports and Ranges of the future. Wi-Fi and EDFA-enhanced FSO communication techniques do not overlap significantly in their basic functional utilities, providing different data rates and non-overlapping range capabilities. In space, though, FSO systems can provide enhanced communication security relative to existing satellite-satellite microwave links. Through Wi-Fi and Wi-Fi 5 wireless Ethernet communications, data transfer rates into the hundred

¹⁴⁵ In addition, unlike normal microwave satellite-to-satellite transmissions, such FSO links are immensely more secure, as there is essentially no possibility for intercepting any communications transmitted over the links except from another satellite that is on-orbit.

¹⁴⁶ A malfunction of the launcher's upper stage left the satellite in a lower than intended orbit. After launch, the orbit was lifted using the satellite's own propulsion systems to an altitude of 31,000 km where the laser-link demonstration was done. To move on to its permanent home in the intended geo-stationary orbit, 36,000 km above the Earth, the satellite will use its newly designed ion propulsion system using only 20 kg of xenon gas as fuel.

¹⁴⁷ Mechanical Engineering Magazine, March 2002.

¹⁴⁸ <http://telecom.esa.int/artemis/fileincludes/overview/overview.cfm>

¹⁴⁹ Design News, May 20, 2002, p. 16.

of Mb/s are possible with hardware that is either available now, or which will become available within a few years. For higher data rates, and for truly secure space-based links, FSO communications can provide the needed point-to-point backbone communication capability as well as the close-in LAN capability. The optimal advanced Spaceport and Range architecture of the future will therefore likely be a mix of wireless Ethernet and FSO communication systems (both terrestrial and space-based) in order to fit the matrix of data rates versus communication distance versus security, and whether point-to-point or multi-casting over wide areas is required. Continuing in the tradition of the optical telegraphs of Polybius in 150 BC and of Chappe in the 18th – 19th Centuries, future FSO communications systems will similarly provide optical communications for the Spaceports and Ranges of the 21st Century and beyond.

4.4 SPACEWIRE

Spacewire, a standard that governs high-speed data link communication protocols and requirements for use on space payloads, was:

- *Prepared* by the European Cooperation for Space Standardization (ECSS) E-50-12 Working Group
- *Reviewed* by the ECSS Technical Panel
- *Approved* by the ECSS Steering Board
- *Published* by the European Space Agency

Spacewire is based on multiple standards, including the DS-DE (Data Strobe, Differentially Ended¹⁵⁰) part of the IEEE 1355-1995 Standard, as well as the ANSI TIA/EIA-644 Standard and the IEEE 1596.3-1996 LVDS (Low Voltage Differential Signaling) Standard. Its primary goal is to support equipment compatibility and re-use at both the component and system level within spacecraft. The present version of the Spacewire standard is ECSS-50-12 Draft 2 dated December 2001.

Spacewire enables the sending of data at speeds ranging from 2 Mb/s to 400 Mb/s from unit to unit. For noise immunity, it encodes data using two differential signal pairs in each direction. Spacewire links are full-duplex, point-to-point, serial communication links. The requirements for the Physical Level, Signal Level, Character Level, Exchange Level, Packet Level, and Network Level are contained in the requirement clauses of the Spacewire standard. In addition, Error Recovery schemes and conformance statements as needed to establish Spacewire compatibility requirements for components and systems are also included in the Spacewire standard. Together, these layered requirements define the necessary physical interconnection and data communication protocols required for Spacewire to work reliably, to meet the EMC (Electromagnetic Compatibility) specifications of typical spacecraft, as well as defining the higher layer formatting and networking functions. The Spacewire standard also contains detailed definitions the terms used in the standard such that precise communication of the requirements can be clearly understood by both equipment designers and integrated system users.

¹⁵⁰ i.e., a link with differentially encoded data and strobe signals

Specifically, the Spacewire Standard defines:

- A. The Physical Level
 - 1.) Connectors
 - 2.) Cables
 - 3.) Cable assemblies
 - 4.) Printed Circuit Board Tracks

- B. The Signal Level
 - 1.) Signal Encoding
 - 2.) Voltage Levels
 - 3.) Noise Margins
 - 4.) Data Signaling Rates

- C. The Character Level
 - 1.) Data and Control Characters used to manage the flow of data across the link

- D. The Exchange Level
 - 1.) Protocol for link initialization
 - 2.) Flow Control
 - 3.) Link Error Detection
 - 4.) Link Error Recovery

- E. The Packet Level
 - 1.) Defines how data for transmission over a Spacewire Link is split up into packets

- F. The Network Level
 - Defines the structure of a Spacewire Network
 - Defines the way in which packets are transferred from a source node to a destination node across the network.
 - Defines how link errors and network level errors are handled

In order to meet the EMC and ESD (Electro-Static Discharge) requirements, Spacewire cables are comprised of four twisted pair wires with a separate shield around each twisted pair and an overall shield. With this well-shielded cable design, Spacewire links support operation aboard spacecraft while permitting cable runs up to 10 meters in length. The eight signal contacts resulting from the four twisted pair wires, along with the screen termination (shield) contact, are connected using nine-pin micro-miniature D connectors that are qualified for space use.

In addition to the well-shielded cables, the characteristic impedances are matched to the line termination impedances to avoid signal reflections, and the data skew (offset) between each signal in a differential pair and between data and strobe pairs are specified

such that the operation over the cable runs up to 10 meters in length are not adversely affected due to equipment termination and time signaling issues. The actual characteristic impedance required for circuit board traces including backplanes interfacing to the Spacewire cables is 100 Ohms, differential.

Low Voltage Differential Signaling (LVDS) is specified as the signaling technique used over the Spacewire cables. LVDS interconnects use balanced signals to provide a very high-speed interconnection while using a low voltage swing (350 mV, typical). Because balanced signaling is used over shielded twisted pair cables, adequate noise margin is met in spite of the low voltage swings employed. At the same time, because only low voltage swings are used, slew-rate limits within the internal transistor circuitry are kept within the ranges whereby very high speed signaling is kept possible. The actual LVDS mode of operation is current mode logic. Although the voltage swings are low, through using a current source that provides a constant 3.5 mA of current the current is kept nearly constant. Because this current is routed only, and is not switched ON and OFF, saturation affects are avoided entirely, and re-routing of current for the logic states is possible within the very short times consistent with supporting data rates up to 400 Mb/s. In addition to the speed advantages of LVDS, LVDS also provides an inherent fail-safe mode. The receiver automatically goes to a HIGH state, which is the inactive state, whenever the receiver is powered and the driver is not powered or is disabled, when the receiver inputs are accidentally shorted together, and when the receiver input wires are disconnected and are in an open circuit configuration. Whenever the receiver is not powered, its input goes to a known high-impedance state ($> 100 \text{ k}\Omega$). Together, these characteristics ensure that only known logic states result from all fault conditions, in contrast to earlier-generation voltage mode logic in which undefined states often could result.

The only competing technologies that provide comparable speeds to LVDS are ECL/PECL (Emitter Coupled Logic, Positive Emitter Coupled Logic). These earlier current mode logic families typically use only single-ended modes of operation, which provide a greatly lessened noise immunity capability, relative to the differential mode of operation used by LVDS. In addition, the ECL/PECL driver/receiver pairs consume 120 mW at the ends of each cable, versus the only 50 mW required for supporting LVDS. LVDS is therefore much more compatible with the high EMC levels typically seen aboard spacecraft, while simultaneously achieving the least possible power consumption.

Timing in Spacewire is accomplished through DS (Data-Strobe) encoding. In this method of encoding, the data and clock are encoded together such that the clock can be recovered through an exclusive-OR (XOR) operation between the Data and Strobe lines. The data values are transmitted directly and the strobe signal changes states only when the data remains constant from one bit interval to the next interval. The same timing technique is used in both IEEE 1355-1995 and IEEE 1394-1995 (Firewire). The advantage of DS encoding is to increase the skew tolerance to almost 1-bit, versus a maximum of 0.5-bit maximum skew tolerance for simple data and clock signaling.

The Spacewire standard defines the Character Level along the same character protocols as are defined in IEEE 1355-1995, but additionally extends the protocols to include Time Codes to support the distribution of system time information. Two types of characters are supported. Data characters hold a parity bit, a data control flag, and an 8-bit data value that is transmitted least significant bit first.¹⁵¹ The parity bit is set to produce an odd parity when appended to the previous 8-bits sent in the last character. The data control flag, by being set to ZERO, identifies the presence of a data character. If the data control flag is set to ONE, then the presence of a control character is denoted. Control characters are formatted similarly to data characters, containing a parity bit and up to four each two-bit control codes. Additionally, to provide the capability to form longer control codes, escape codes are also supported. With these extensions, Spacewire character protocols are such that presently required data characters, as well as rather flexible growth potentials regarding control characters and codes, are all supported.

Above the Character Level is the Exchange Level. The Exchange Level provides provisions for initialization, flow control, detection of disconnect errors, detection of parity errors (computed from the parity bits provide in the Character Level), and link error recovery. Considerably more capability in the Exchange Level for Spacewire is implemented than in the earlier Exchange Level defined for IEEE 1355-1995. Specifically, once parity errors are detected in the just-sent data or control character, complete recovery is attempted through the link error recovery mode. This is done through a re-synchronize and restart technique using an “exchange of silence” protocol. The end of the link that detects a parity error goes silent, and this forces the other end of the link, that actually transmitted the character containing an error, to recognize the silence as being a link disconnect. The end that originally transmitted the character with the error then waits for 6.4 μ s. The end that detected the error then waits for an additional 6.4 μ s as well. At this point, an additional delay of 12.8 μ s occurs, at which time a normal NULL/FCT handshake is used to re-establish the connection and ensure proper synchronization. The result is a robust protocol for the Exchange Level.

The next level above the Exchange Level defined in Spacewire is the Packet Level. The Packet Level protocol follows the Packet Level protocol defined in IEEE 1355-1995. Each individual packet consists of a destination address, cargo, and an end-of-packet marker. Support for wormhole packet routing, i.e., direct connection routing, is provided for wormhole packet routing switches. Wormhole packet routing is supported because it reduces the amount of buffering that would otherwise be required. Wormhole packet routing eliminates conventional store and forward operation, since it results in the immediate re-transmission of an incoming packet prior to the receipt of the entire incoming packet. Provided that error correction protocols are carefully followed, wormhole packet routing does not cause any permanent data loss in the event of transmission of a packet containing an error, and increases throughput while reducing memory hardware storage requirements.

¹⁵¹ LSB first is also known colloquially as little-endian in some circles. This is in contrast to big-endian for describing the reverse condition. See: <http://info.astrian.net/jargon/terms/l/little-endian.html>

Above the Packet Level is the final Network Level contained in Spacewire. The Network Level defines the Spacewire Network, describes the components that make up a Spacewire Network, explains how packets are transferred across a Spacewire Network, and defines how the Spacewire Network recovers from errors. Fundamentally, a Spacewire Network is comprised of a collection of Spacewire Nodes that are interconnected either by Spacewire Routing Switches or Spacewire Links. Spacewire Nodes provide and receive packets, as the sources and destinations of packets, and provide all the necessary interfaces to the application system(s). Spacewire Routing Switches provide link interfaces connected together by a switch matrix to allow any link input to pass the packets it receives on to any link output for re-transmission.

Due to the physical limitation of providing only 10 meters for the maximum distances allowed between units, the need to support Spacewire interconnects relative to future advanced Spaceports and Ranges is likely to be limited. The best uses will be for performing final payload checkouts prior to the departure of the aerospace plane or launch vehicle. These will likely occur at various points in the staging of the payload, up to just before departure. Although Spacewire Networks could be used to interconnect some of the additional various equipments within the staging and final configuration areas of the Spaceport, this is not likely. Because of the lack of standard Spacewire interfaces on future planned test equipments, as well as the rather limited 10 meter maximum distance imposed by the Spacewire standard, the likely outcome will be to reduce the need for Spacewire as a general purpose interconnection technique. The predominant support for Spacewire will likely be limited to just performing final checkouts immediately prior to the launch of payloads built around the Spacewire standard.

Potential users of Spacewire also need to be aware that the serial link always starts at a 10 Mb/s rate, then goes up (or, in unusual cases, down) to the maximum rate that is reliably supported on both ends. However, there is also a 2 Mb/s minimum data rate that exists, too, that is determined mostly by time-out hardware issues that exist within the link. So, although there is a minimum data rate of 10 Mb/s in the spec, it is not really the minimum rate that can be supported, and future Spaceport and Range plans need to take this into account if lower data rates are required, to avoid Spacewire link timeout problems. One way to avoid this problem, for lower data rate items, is to encode user data on a higher rate signal, before sending the composite higher-rate signal through a Spacewire link. This would potentially impose difficulties for Spaceport and Range users unless it were made transparent to users.

4.5 FIREWIRE

Firewire, also known as 1394 and i-link, is an older serial digital interface standard that governs high-speed, real-time, data-link communication protocols and requirements, and operates at speeds up to 400 Mb/s, with up to 63 simultaneously interconnected high-speed devices.^{152,153} Apple Computer first developed Firewire in 1986 on a closed-computer architecture, and to honor the speed of the interface standard trademarked the resulting technology with the name “Firewire”. By 1987, Apple had completed an internal specification for the link and had resolved all of the early difficulties in implementing the specification. The Institute of Electrical and Electronic Engineers (IEEE) adopted the Apple specification in 1995 and coined the IEEE 1394-1995 standard to document the Firewire specification.¹⁵⁴

Unfortunately, one must become licensed for 49 groups of patents owned by nine separate corporations through the 1394 Licensing Authority even to view the current Instrument and Industrial Control Protocol (IICP) technical specification involving Firewire.¹⁵⁵ The fee for licensing varies from \$8,000 to \$4,000 as of May 2002 depending on company gross revenues.¹⁵⁶ Further, each licensed company must presumably pay royalties to use the standard in any hardware delivered using the technology. (Short of paying the fee, it is not possible to see what the terms and conditions of licensing actually are.) In spite of its performance, the closed-architecture mentality has greatly hampered the acceptance of the technology and has greatly pushed up implementation costs relative to lesser performing, cheaper, open-architecture technologies. It has also gone counter to the generally accepted principal of providing open-standards, free of cost, to all. The end-result has been that Firewire/1394 remains a niche market technology, unaccepted by the digital interface technology market at large, in spite of its many performance advantages.

IEEE 1394-1995 includes such advanced features as self-configurability, guaranteed Quality of Service (QoS) (which is needed to support real-time multi-media applications), peer-to-peer networking, and an ability to commingle low-speed and high-speed devices on a single bus, all implemented in a low-overhead protocol. As a result,

¹⁵²1394 Trade Organization Website, <http://www.1394ta.org/Download/Technology/iicpPaper2.pdf>, retrieved 20 May 2002.

¹⁵³Yoshida, Junko, *Association comes out fighting for Firewire*. Electrical Engineering Times, May 6, 2002, <http://www.eet.com/story/OEG20020506S0041> retrieved 20 May 2002.

¹⁵⁴ 1394 Trade Organization Website, <http://www.1394ta.org/Technology/index.htm>, retrieved 20 May 2002.

¹⁵⁵ 1394 Licensing Authority Website, <http://www.1394la.com/>, retrieved 20 May 2002.

¹⁵⁶1394 Trade Organization Website, <http://www.1394ta.org/About/Join/Application/>, retrieved 20 May 2002.

the types of products that support the IEEE 1394-1995 standard today include multi-media products such as digital VCRs, digital cameras, and digital video editing equipment with a strong need for true real-time digital interface connectivity. Likewise, newer versions of Microsoft Windows now include native IEEE 1394-1995 support, allowing PCs to operate with the multi-media products that now include IEEE 1394-1995 functionality.¹⁵⁷

Yet, in spite of the fact that IEEE 1394-1995 promised to deliver a truly universal data connection for almost any computer, peripheral application, or consumer product requiring high-speed digital connectivity, the mass market has largely ignored IEEE 1394-1995. In many ways, Firewire/1394 now competes rather unsuccessfully with the more primitive digital interface technologies of RS-232 Serial Interfaces, USB (Universal Serial Bus), DVI (Digital Visual Interface), as well as with both Wired and Wireless Ethernet. In addition, Hitachi, Matsushita, Philips, Silicon Image, Sony, Thomson, and Toshiba teamed in April 2002 to work on a standard known as the High Definition Multimedia Interface (HDMI), planned for a debut at the 2003 Consumer Electronics Show in Las Vegas, NV, to compete with Firewire/1394 on the issues where it does excel, in real-time multi-media connectivity. The future for Firewire/1394 appears bleak. It has already lost out on the existing, non-real-time, low-cost digital interface technology market. It also may very well lose its present niche market in interconnecting real-time multi-media devices.¹⁵⁸

The reason comes down to just two major issues: an overly disruptive implementation complexity, and cost. The competing alternative digital interface technologies, although having no significant QoS features, are inherently supported by legacy IBM-PC clone hardware, and provide adequate performance for many applications. These less-capable technologies have developed slowly, with no perceived learning curve governing their use. Firewire/1394, on the other hand, is not an incremental technology. It broke with the existing technologies so as to add the high-level features of self-configurability, QoS, and the ability to commingle low-speed and high-speed devices. This was probably bad enough, but there was one other factor that played against the adoption of the standard for all digital interface uses: high cost. The total cost is high because of an underlying technical complexity, lack of supporting hardware, and Intellectual Property licensing fees even to view the specifications. There were, until mid-2002, no easy-to-adopt reference design platforms available providing proven-to-interoperate, low-cost reference designs. One-stop integrated solutions, integrating proven designs in silicon, complete with firmware and software, which are so very necessary to bring down the cost to implement Firewire, have only come onto the market in mid-2002. In many ways, Firewire/1394 is likely a technology that is too much, too little, too late, and too costly, in

¹⁵⁷ 1394 Trade Organization Website, <http://www.1394ta.org/Technology/index.htm>, retrieved 20 May 2002.

¹⁵⁸ Yoshida, Junko, *1394 trade group fights back in home nets*. Electrical Engineering Times, May 13, 2002, p. 20.

terms of market acceptance. Closed-architectures often inherently work from a severe cost disadvantage relative to open-architectures.

To combat the difficulties in a perception that has become a reality for IEEE 1394-1995 proponents, the 1394 Trade Association has started to revise the IEEE 1394-1995 standard to address Ethernet competition through launching Firewire/1394 specification enhancements to add Internet Protocol operation over 1394, Wireless 1394, and 1394 LAN home-networking. According to published reports, a protocol adaptation layer is even being developed in the IEEE 1394-1995 specification to permit the running of two different logical networks over one medium, to permit Firewire to co-exist with Ethernet in a new IEEE 1394-1995 network. To support this further, the 1394 Trade Association is also developing a hardware reference platform with embedded Intellectual Property (IP) software content.

Adding further complexity, and a larger learning curve, will likely prove even more detrimental to the goal of achieving acceptance in the larger digital interface technology competition. It is likely that Firewire/1394 will not become the standard to which all users migrate. Instead, it is likely that the new Firewire/1394 standard will remain a niche standard, providing a rather complex, expensive solution to a problem that not every user has, or can afford.

Relative to using Firewire/1394 on the Spaceports and Ranges of the future, it is not likely that this technology will be more than an outlier in terms of its utilization. For niche needs, with high QoS, quick reconfigurability, and where cost does not greatly matter, Firewire/1394 may have a small role. Other than that, however, it is not likely to play any significant role.

4.6 COMMERCIAL SATCOM UTILIZATION & RE-USE

The transition to commercial SATCOM (Satellite Communication) links, rather than to new or expanded Government SATCOM assets, until just a few years ago appeared firmly established as the obvious way to accommodate future communications growth while saving taxpayer dollars. With the numerous commercial LEO and MEO satellite systems then planned, it appeared that no Government dollars would be needed for serving the vast majority of mobile and fixed SATCOM users. The hope was that a totally space based communications system, based in large part on a growing reliance on commercial SATCOM links, could meet the majority of upcoming range needs based solely on investments that were already being supported by the commercial sector. Likewise, the belief was that by transitioning to a space based communications system, this would in turn ultimately lead to a global approach for supporting future Spaceports and Ranges. The ultimate plan would be simply to depend on the private sector to develop, field, and maintain competing constellations of privately owned satellite systems that could provide expanded data connectivity for use at future Spaceports and Ranges throughout the world. Among the commercial SATCOM systems then planned, were Iridium, Teledesic, Spaceway, Astrolink, Globalstar, and Skybridge.

What a radical difference a few years make. Today, Globalstar is in operation with a largely fixed, but non-growing subscriber base, and has undergone bankruptcy reorganization. Iridium has likewise undergone bankruptcy reorganization and a government bailout, but remains in operation. Teledesic (which some now refer to as “*Teledead*”) is officially cancelled, Skybridge is on indefinite hold, and Astrolink has announced a total suspension of their SATCOM project. Overall, the viability of commercial SATCOM subscriber businesses has been cast in a questionable light with the only two operational systems in, or still emerging from, bankruptcy, and with most others on hold or cancelled. Depending on any of the existing, or planned, commercial SATCOM systems appears risky.

The most popular handheld satellite system in use today is Globalstar. For the calendar year quarter ending March 31, 2002, Globalstar L.P.'s net loss declined to \$129 million, and the number of subscribers remained stable at only 69,000. Globalstar's rate of new subscriber growth has slowed from previous quarters, largely due to ongoing restructuring activities involving several of the company's service providers, where, in some cases, ownership changes disrupted business development efforts. Whatever the reason, the number of subscribers is not growing significantly.¹⁵⁹ Because of the failure to capture increasing numbers of subscribers, Globalstar defaulted on repayment of its debt, commencing in early 2001.¹⁶⁰ Globalstar subsequently filed voluntarily for Chapter

¹⁵⁹ <http://www.globalstar.com/EditWebNews/307.html>

¹⁶⁰ *Iridium Satellite Phone Re-launch*, BBC News, 28 March 2001, http://news.bbc.co.uk/1/hi/english/business/newsid_1247000/1247385.stm

11 bankruptcy on February 15, 2002, and court approval for reorganization was granted on February 21, 2002, under which Globalstar continues to operate for the near term.¹⁶¹

The second most popular handheld satellite system in use today is Iridium, originally developed by a group of companies led by Motorola. Whereas Globalstar does not provide uniform coverage of both inhabited and uninhabited parts of the world, Iridium is the only truly global and mobile satellite systems providing both voice and data operation at sea, over the poles, and everywhere else on Earth. Following the highly publicized \$5 billion bankruptcy of Iridium LLC in August 1999, Iridium Satellite LLC, a privately held corporation, acquired the assets of Iridium LLC in December of 2000 for \$25 million.¹⁶² These assets included the satellite constellation, the terrestrial network, Iridium real property and intellectual property. Funded by a group of private investors, Iridium Satellite LLC has essentially no debt and has set monthly operating fees for customers that are but a small fraction of the cost under the previous Iridium system. The rate presently charged for using Iridium is roughly \$1.50 per minute, in contrast to over \$7.00 per minute charged under the original billing rates.¹⁶³ Through its own gateway in Hawaii, the U.S. Department of Defense presently relies on Iridium for global communications capabilities.¹⁶⁴ With the retirement of \$5 billion of debt through bankruptcy, and upon receiving financial support of from \$72 million to \$252 million through 2002 from the Department of Defense, Iridium should remain viable for the near term.¹⁶⁵

Unfortunately, the data throughput capacity of both Iridium and even Globalstar is miniscule relative to present-day wired networks. The problem of financial viability likewise remains for all portable/mobile equipment SATCOM providers, and is only worsened by the recent financial histories of both Globalstar and Iridium. Based on recent history, the sector fundamentally appears incapable of returning a reasonable return *on* principal, or even a return *of* principal.¹⁶⁶ Fundamentally, though, neither Globalstar nor Iridium comes close to competing with terrestrial data throughput rates. Iridium provides just 2400 bps (2.4 kb/s) through a single channel. By simultaneously using multiple channels, it is possible to increase the throughput to around four to perhaps as much as ten times the nominal 2.4 kb/s data rate through Iridium. Globalstar

¹⁶¹ <http://www.spacedaily.com/news/globalstar-02a.html>

¹⁶² *Iridium Satellite Phone Re-launch*, BBC News, 28 March 2001, http://news.bbc.co.uk/1/hi/english/business/newsid_1247000/1247385.stm

¹⁶³ *Iridium Satellite Phone Re-launch*, BBC News, 28 March 2001, http://news.bbc.co.uk/1/hi/english/business/newsid_1247000/1247385.stm

¹⁶⁴ http://www.iridium.com/corp/iri_corp-story.asp?storyid=2

¹⁶⁵ http://www.iridium.com/corp/iri_corp-news.asp?newsid=14

¹⁶⁶ A paraphrase of what American humorist Will Rogers once stated, “It’s not my return *on* my principal that worries me, it’s the return *of* my principal.”

provides data rates of only 9.6 kb/s. This data rate is but a small fraction of the data rates possible through even a conventional 56 Kb/s dial-up modem. Relative to a Cable Modem or a DSL connection, both Globalstar and Iridium fall far short of being a viable wideband portal to the Internet from an isolated LAN or WAN.

The benefit of always on, two-way, high-speed Internet access for remote sites not having the option of using DSL over phone lines, Cable Modems, or even dial-up connectivity remains obvious. Several companies are still planning to begin service in 2003 or 2004; despite the financial shortcomings of the first generation, two-way, low-speed services provided by Globalstar and Iridium. WildBlue is likely to be one of the leaders in providing such service for North America.¹⁶⁷ Data throughput of up to 3.0 Mb/s for the United States and parts of Canada is planned for availability in 2003. WildBlue uses a 26-inch dish connected to a WildBlue Modem to provide always on, high-speed Internet access for up to eight computers within a SOHO (Small Office, Home Office) environment. Unlike the Iridium system that is based on a constellation of 66 LEO satellites, WildBlue is based on a single GEO satellite. Spot beams at 20 GHz and 30 GHz elegantly address the need for providing high bandwidth Internet service on demand for remote users in North America and parts of Canada. Although WildBlue is less ambitious than, say, Iridium, which provides truly global coverage, the benefit to cost ratio is drastically improved. Pricing is not yet announced, but the stated goal is to provide flat rate, unlimited wireless Internet service that is comparable in monthly cost to a mini-satellite TV system. (Mini-satellite systems presently cost around \$50 to \$70 per month, with further price drops to around \$30 per month promised by some industry leaders.) WildBlue may very well have a financial crisis looming in its future unless market conditions change appreciably. (WildBlue uses the DOCSIS cable standard for its protocol. This is the same protocol as used on high-speed Cable Modem connections today, as discussed earlier.)

It is certainly good that new, more cost-efficient systems are being proposed, for the existing mini-satellite Internet Service Provider market is in a total state of chaos. This chaos is due to the bankruptcies of multiple companies, carriers, and equipment suppliers, in addition to industry consolidations and a proposed purchase by EchoStar of Hughes Electronics, owner of DIRECTV. Likewise, the hybrid satellite/terrestrial systems, based on integrating DSL with satellite links, are similarly in a total state of confusion.

To understand the current DSB/DSL chaotic situation better, it is necessary to understand a brief history of the companies involved. (Note: DSB – Direct Satellite Broadcast; DSL – Direct Subscriber Line, i.e., a phone line broadband Internet solution.) Hughes Electronics, a subsidiary of General Motors Corporation, merged with United States Satellite Broadcasting Company, Inc. (USSB) in 1998 to acquire the business and assets of USSB in a transaction valued at approximately \$1.3 billion at the time (on the basis of a stock price of \$38.25 a share in Hughes Electronics [GMH]). DIRECTV thereby

¹⁶⁷ <http://www.WildBlue.com/flash.htm>

became the world's largest DSB company.¹⁶⁸ With this purchase, DIRECTV essentially consolidated the DSB market, sharing the DSB market only with EchoStar. At present (June 2002), DIRECTV has approximately 10 Million subscribers in contrast to EchoStar's 7 Million subscribers.

Unfortunately, the price of becoming the dominant DSB company became much costlier than planned, for the stock price of Hughes Electronics dropped to only \$13.05 (by October 2001), causing an accounting loss in terms of goodwill of nearly \$860 Million relative to the 1998 purchase price of USSB. The result was that in October 2001, EchoStar tendered an offer to purchase Hughes Electronics, by which it would be possible to consolidate completely the DSB market, and simultaneously bail out Hughes Electronics from its mountain of debt through achieving further efficiencies of scale to reduce operating costs through merging DIRECTV and EchoStar.

Meanwhile, consolidation was occurring in the DSL world, as well. WorldCom bought Rhythms NetConnections' assets at bankruptcy court for \$31 million. (Rhythms was a former popular and very large, though unprofitable, DSL provider for residential and business customers in fifty-five major markets.) WorldCom then targeted business customers with the assets bought at the bankruptcy auction, and further signed an agreement in March 2002 to expand DSL services to DirecTV's customers in the West and Midwest.¹⁶⁹ WorldCom's plan was to take advantage of the telecom industry turmoil, and further consolidate multiple technologies with the remaining assets of former bankrupt companies; thereby capturing as much of the mini-satellite and DSL Internet Service Provider market as possible. Then, in June 2002, WorldCom itself imploded upon the discovery of a fraudulently misstated \$3.8 billion improperly accounted for as revenue in place of expenses, and bankruptcy now appears inevitable for WorldCom itself.

As for EchoStar's proposed takeover of DIRECTV, the merger process that started in October 2001 is still undergoing government scrutiny, for it will largely eliminate competition in the DSB market, while enabling mini-satellite services to compete with cable. For this reason, this takeover is not likely. Additionally, the FCC suspended a review of the DIRECTV deal in March 2002.¹⁷⁰ The result was a further slide in Hughes Electronics (GMH) stock to a price of \$10.05 (July 9, 2002 close.) The total loss to Hughes Electronics for the purchase of USSB now hovers around \$1 Billion (as of July 2002), and it is still unclear whether EchoStar can purchase DIRECTV. If not, it appears likely that Hughes Electronics may very well slide into Chapter 11 bankruptcy itself.

¹⁶⁸ *Hughes Buys United States Satellite Broadcasting*. Space Daily. December 15, 1998. <http://www.spacedaily.com/news/hugh-98l.html> retrieved 9 July 2002.

¹⁶⁹ Smith, Jeff. *A Dream Deferred. High-speed DSL Internet access remains out of reach for the majority of consumers*. Rocky Mountain News, Colorado's First Newspaper. April 1, 2002.

¹⁷⁰ *FCC Suspends DirecTV Deal Review*. Space Daily. March 8, 2002. <http://www.spacedaily.com/news/satellite-biz-02q.html> retrieved 9 July 2002.

From this short financial history of the DSB/DSL market, it is obvious that for a multitude of reasons, the ultimate fate of millions of mini-satellite and DSL ISP customers remains uncertain at this time. Although there is clearly a market for providing broadband Internet service to SOHO customers, it remains unclear which company, or companies, will survive, and whether any will emerge dominant in this market.

Meanwhile, until the financial smoke clears and companies either shut their doors or merge, several service alternatives still exist. A lower-performance, but higher priced, alternative to the two-way satellite data transport planned by WildBlue exists today for sites served in North America by DSL through the local phone company. DIRECTV DSL is a replacement for an earlier hybrid satellite/phone system that used a satellite distribution downlink with a phone-line dial-up uplink connection.¹⁷¹ (Telocity bought the rights to the DIRECTV name from Hughes, and has renamed itself as DIRECTV Broadband, Inc., selling what they call DIRECTV DSL). DIRECWAY, meanwhile, has retained the rights to the original hybrid satellite/phone-line system.

DIRECTV DSL uses DSL for operation in both directions. Downloads can be as fast as 784 Kb/s for SDSL and 1.5Mbps for ADSL. Upload speed is typically 128Kbps for ADSL and 392Kbps for SDSL. Pricing for DIRECTV DSL is presently \$49.99.¹⁷² Pricing for SDSL through local phone companies varies, but is approximately the same cost per month. The total monthly cost for DIRECTV DSL therefore runs around \$100.

DIRECWAY is the continuation of the legacy hybrid satellite/phone-line data network system, and provides two-way satellite Internet access without the phone-line. DIRECTV is possible on the same equipment (mini-satellite TV system) as DIRECWAY. Current pricing for the DIRECWAY hardware is \$670, and monthly service is additional.

The legacy hybrid satellite/phone-line system is known today as DIRECPC. It provides satellite downloads at speeds up to 400 Kb/s with 28 Kb/s or 33 Kb/s uploads over conventional phone lines. Pricing for DIRECPC hardware runs \$280 with monthly service billed extra, and with additional phone line billing required for the dial-up portion of the link.¹⁷³

Whatever the outcome, the commercial SATCOM market for mobile and data-hungry computer users remains in a state of chaos, and will continue to do so for the near future.

¹⁷¹ <http://www.theuse.net/telocity/>

¹⁷² <http://www.theuse.net/telocity/dsl-packages.html>

¹⁷³ http://www.expertsatellitedish.com/satellite_provider.htm

Long-term, the emergence of disruptive technologies in the form of systems such as from WildBlue and Eutelsat may settle the commercial SATCOM data issue.

Relative to the impacts on future Spaceports and Ranges, the dependence on commercial SATCOM, other than on Iridium or Globalstar appears unwise. There is excessive financial uncertainty to plan for two years out, let alone out to 2025 or 2030. This technology area will need to be revisited once the outcome becomes better known relative to DIRECTV, EchoStar, WildBlue, etc. In the meantime, it appears likely that Wireless Ethernet tied into existing communication infrastructures will be a wiser choice than even a partial dependence on commercial SATCOM technology for mobile and fixed remote data users. Short of moving to a Spaceport launch platform at sea, Wireless Ethernet appears safe in terms of providing the necessary levels of performance consistent with anticipated scenarios.

4.7 ULTRA-WIDEBAND

4.7.1 Background

UWB (Ultra Wideband) is an emerging and extremely promising wireless technology presently allowed operation under a restrictive Part 15 approval of the FCC (Federal Communications Commission). This is in cautious response to the concerns filed by more than nine hundred companies from around the world with the FCC responding to an FCC NPRM (Notice of Proposed Rule Making) issued May 10, 2000. In this NPRM, the FCC solicited inputs related to any unintended interference likely to occur by permitting UWB devices to operate. Significant rationalizing, by more than nine hundred companies were received in numerous, voluminous, and often acrimonious response filings, even to the point of claiming UWB technology would cause planes to fall from the sky and would even have prevented trapped cell phone users from using cell phones in the World Trade Center complex on September 11th, 2001.¹⁷⁴

Standing in opposition to this disruptive UWB technology are all the major wireless carriers, satellite radio companies, wireless Internet service providers, commercial GPS-based surveying companies, cell-phone manufacturers, wireless Ethernet equipment manufacturers, data compression companies, and every other company with a vested economic interest in existing wireless technology in the world. If unrestricted UWB technology were permitted by the FCC, all these companies stand to lose significant sales revenue to smaller, startup UWB companies; thereby losing their economic dominance in key portions of existing radio technologies.

Not only companies with a business interest in wireless communications oppose UWB technology. The Federal Aviation Administration (FAA) has also opposed the technology due to concerns regarding its possible detrimental impacts on aviation communication and navigation systems. Additionally, the U.S. Department of Justice (DoJ), has opposed the technology, as it would permit the use of LPI (Low Probability of Intercept) transmissions that would require costly development of new wireless intercept equipment by the Federal Bureau of Investigation (FBI) to continue the interception (tapping) of private wireless transmissions. The 1995 capture of famed computer criminal Kevin Mitnick was only accomplished through interception of his cellular modem phone calls in North Carolina. This was done by the FBI using cell-phone interception equipment known as ‘Triggerfish’.^{175,176,177,178} If UWB versions of cell

¹⁷⁴ *An emerging wireless technology fights for its life*, Red Herring, Red Herring Communications, Inc., San Francisco, CA, June 2002, pp. 20-21.

¹⁷⁵ Carsten, Keith A. *Bringing the Cyber-Criminal to Justice: An Essay for the Technologically Impaired*. Stetson University, 1997. <http://www.law.stetson.edu/courses/computerlaw/papers/kcarstenf97.htm>.

¹⁷⁶ Shimomura, Tsutomu and Markoff, John. **Takedown: The Pursuit and Capture of Kevin Mitnick, America's Most Wanted Computer Outlaw - By the Man Who Did It**. Hyperion. ISBN: 0786862106. Shimomura unfortunately neglects to mention that Triggerfish equipment was actually used by the FBI to

phones and other wireless products were permitted, development of a newer and more costly generation of cellular interception equipment would be required, to prevent the ‘good-guys’ from falling behind in the technology needed for monitoring communications from criminals and terrorists.

The capabilities engendered by UWB technology, if investigated on a purely technical basis rather than on an economic basis, are intriguing. By current FCC definitions, UWB is defined as a communication technology using 25%, or greater, fractional bandwidths, or occupying more than 1.5 GHz of transmitted bandwidth.¹⁷⁹ UWB largely renders data compression technology obsolete. The requirement to pack more and more bits into a *limited* bandwidth is largely eliminated. Furthermore, in spite of occupying very large bandwidths, UWB is usually benign to existing wireless systems and services. In terms of causing interference to existing services, based on extensive testing by the National Telecommunications and Information Administration, and as documented in reports to President Bush and to the FCC, UWB technology has minimal risks to existing wireless systems when operated between 3.1 GHz and 10.6 GHz at less than very high power levels. From early NTIA test results, and from the debate in the press that has ensued relative to UWB technology, it is obvious that economic issues are the predominant concern instead of real interference issues, at least for many existing companies.

Historically, Part 15 rules have governed the use of low-power, unlicensed equipments that are permitted to operate without prior coordination among users, after the hardware is FCC type-accepted. Part 15 devices have previously been narrowband in nature, in contrast to UWB’s inherently broadband characteristic. Typical uses of Part 15 transmitters have included garage door openers, baby monitors, cordless phones, and

pinpoint Mitnick’s location, instead of his own, more primitive, cell phone intercept equipment. Shimomura’s gear was used initially to try to capture Mitnick, but was not powerful enough.

¹⁷⁷Nelson, Sharon D., and Simek, John W., *Takedowns: Legendary Successes in Computer Forensics*, VSB Committee on the Technology and the Law, April 2002.
http://www.vsb.org/publications/valawyer/apr02/tech_law.pdf retrieved May 31, 2002.

¹⁷⁸ http://dede.essortment.com/kevinmitnickco_rmap.htm

¹⁷⁹ This differs from the classic definitions that have been used for over 20 years. The classic distinctions among narrowband versus broadband were based on fractional bandwidth, like the present FCC definition of UWB. However, spread spectrum, and UWB were usually distinguished by the ratios of their transmitted bandwidths relative to their baseband modulation bandwidths. Spread spectrum was the term usually applied when the transmitted bandwidth occupied more than the baseband bandwidth up to 100 times the baseband bandwidth. UWB, however, was generally defined to be when the transmitted bandwidth exceeded 100 times the baseband signal bandwidth. Broadband was the term used when the occupied bandwidth occupied fractional bandwidths of at least 25%, but more often was reserved for only cases exceeding an octave or two of bandwidth. For example, if a 1 GHz carrier were directly modulated with a 250.1 MHz narrowband signal, in the classical definition this would not even be spread spectrum, and barely broadband, let alone UWB. Yet, by the current FCC definition, it is currently considered UWB, irrespective of the relationship between the transmitted bandwidth relative to the baseband bandwidth.

other short-distance, low-power, narrow-band transmitters.¹⁸⁰ By their very nature, using pulse modulation with extremely short-duration bursts of RF (Radio Frequency) energy, UWB transmissions are inherently not narrowband like prior Part 15 devices, but instead occupy extremely wide bandwidths, typically greatly exceeding 1 GHz. Since the correlation bandwidth of the dense urban propagation channel is typically less than 10 MHz over 3.1 GHz to 10.6 GHz, the use of extremely short-duration bursts causing ultra wideband occupancy over much greater than the correlation bandwidth completely mitigates the effects of destructive interference in multi-path signals.¹⁸¹ Because of this characteristic, for example, a high fidelity UWB replacement signal for FM broadcast use would completely avoid the fading so commonly heard when driving through dense urban downtown areas.

As for the upper bound on transmitted UWB bandwidths, the only intentional bandwidth limitation of first generation UWB transmitters was the bandwidth limit of the attached wideband antenna. (This repeats an old practice last used prior to the ban in 1927 of spark-gap transmitters, as discussed later.) As a result, transmitted energy from UWB transmitters originally occupied frequencies reserved for other services, causing numerous political issues to exist. After all, the other services had *paid* the FCC for their spectrum. With the latest ruling from the FCC, constraining UWB output transmitted waveforms to occupy the band from 3.1 GHz to 10.6 GHz, the GPS frequency bands centered around 1575 MHz and 1227 MHz are protected, thereby addressing the concerns of interference to low-level GPS signals.

As a result of the lack of interference, even without GPS protection filtering, as indicated through extensive testing by the National Telecommunications and Information Administration, the FCC approved on February 14, 2002, a First Order and Report (FCC 02-48) amending FCC Part 15 rules to permit the marketing and operating of a limited set of new products incorporating Ultra-Wideband (UWB) technology. The effect of this is that UWB transmissions are effectively not approved for use over distances more than a few hundred feet, in practice. As such, these very weak UWB transmissions do not pose any economic threat to existing wireless carriers providing service over multiple miles, or, essentially, even to wireless Ethernet card makers, whose Wi-Fi cards are capable of operating over distances up to 1,800 feet in open areas.

In addition to the purely technical performance advantages of UWB technology, UWB also has the inherent economic advantages typical of a disruptive technology. UWB transmitters and receivers do not require the oscillators, mixers, filters, and numerous

¹⁸⁰ Even the so-called “secure” spread-spectrum cordless telephones sold for home use occupy bandwidths of only a few MHz. This is considerable processing gain relative to voice bandwidths of less than 6 KHz, but still fundamentally results in a narrowband signal. No interference results from using these cordless telephones to other services.

¹⁸¹ Correlation bandwidth refers to the bandwidth over which a spectral null is typically correlated and all signals fade simultaneously. It is the bandwidth over which a fade exists in, for example, an urban channel. Any signal within this bandwidth is simultaneously lost during fading events, and the fade is said to be ‘correlated’ over this range of frequencies.

other expensive components required in conventional wireless gear. As discussed earlier, UWB likewise eliminates the need for data compression, and for the data compression and de-compression chip-sets, as well as eliminating the dc power required to run the data compression/de-compression chips. The result is that UWB equipment requires low-cost components totaling only around ten percent of the cost of the components required to implement conventional wireless gear. Likewise, UWB gear can use batteries that are only 10% to 25% of the cost, size, and weight of batteries required for existing wireless battery-powered equipment due to improved efficiencies of the short-duration transmitted signals, elimination of data compression, and elimination of other power-consuming functional blocks. Because of these economic and performance advantages, existing wireless companies, whose technologies are based on old-era technology, will suffer immediate price undercutting in addition to obvious technology shortcomings, relative to newer UWB equipment, if in direct competition with UWB equipment. For obvious reasons, established companies do not wish to permit the legislative approval of UWB technology.

Meanwhile, the acrimonious rhetoric continues: “Wireless companies that depend on the FCC to erect barriers to entry and protect their investments in spectrum are misguided. If they had invested in this powerful technology, instead of spending three and a half years to lobby the FCC, they might have developed new ways to lower their network costs and improve their service offerings” was the message carried in one magazine editorial.¹⁸² Whether approved or not, the performance advantages and cost advantages for the consumer would be immense for UWB-based devices, despite the loss of sales of older wireless equipment by established vendors.

Although the basic concepts related to UWB have been proven since the 1980’s for special purpose fielded hardware, and there are commercially developed chip sets presently available to implement UWB technology cost-effectively, the true commercialization of UWB equipment only became possible as of February 14, 2002 with the latest FCC ruling. The FCC expressed its desire to proceed cautiously in FCC 02-48, and identified that a further review of UWB standards will occur within six to eighteen months (relative to February 14, 2002). A much wider approval was hoped for by many of the smaller startups that have invested in the technology, but the present First Report and Order states that more general approval for UWB transmissions will not be reconsidered until more data are available regarding unintended interference due to UWB technology.

Additionally, there is another factor at play at the FCC, too, in addition to the concerns of wireless companies worldwide. UWB technology inherently avoids the “FCC’s favorite money-raising tactic: the spectrum auction.”¹⁸³ Approval of the technology would

¹⁸² *Right the wireless wrongs*. Editorial Page. Red Herring, Red Herring Communications, Inc., San Francisco, CA, June 2002, p. 19.

¹⁸³ *Right the wireless wrongs*. Editorial Page. Red Herring, Red Herring Communications, Inc., San Francisco, CA, June 2002, p. 19.

largely negate the economic viability of numerous prior spectrum auctions held by the FCC, opening the door to serious litigation. Additionally, if approved in the United States, the multiple billions of equivalent US\$ worth of spectrum auctions spent for 3G Wireless technologies in Europe would become worthless, too. These same companies are planning to introduce versions of their 3G Wireless equipment into the United States after conquering Europe.

The fact that UWB technology has proven so controversial resulted in an ultra-conservative initial test phase in the FCC Report and Order of Valentine's Day 2002, permitting only a limited number of low-power UWB applications be fielded in order to avoid any possibility of interfering with existing radio signals, especially low-level GPS signals.

The proven benefits of UWB or, more properly, Time Modulated Ultra-Wideband (TM-UWB) systems are many. TM-UWB systems can provide:

- Voice and data communication with selectable degrees of security
- Indoor, through-the-wall, and perimeter security radar functions
- Precise ranging capability to determine the precise distances between objects with real-time tracking to within an inch
- Elimination of data compression requirements to fit data into pre-set narrow bands
- Nearly complete immunity to multi-path propagation, such as encountered in dense, urban areas, simultaneously increasing data throughput as well as avoiding low signals due to destructive interference of received multi-path signals

With these diverse capabilities, TM-UWB technology can enhance numerous Spaceport and Range disciplines including:

- Wideband operation during a launch event, in spite of considerable multi-path reflections caused by aluminum-based particle exhausts
- Real-time tracking of high cost assets, with high precision
- Reliable, high-speed, secure wireless voice, data and video transmissions inside buildings
- Personal radar for security system functions for perimeter control
- Radar functions, with through-the-wall sensing to penetrate materials such as brick and concrete to provide more defined images than conventional radar for security sweeps of buildings and cargo areas of tractor trailers

Present SBIR investigations of UWB technology are being conducted in coordination with Johnson Space Center to enable in-helmet video transmission in next generation spacesuits.

TM-UWB systems use very low power (i.e., ‘flea-power’ is what some term it; Part 15 levels of 5 mW or less), unlicensed, very short duration (< 2 ns, typically 10 to 1000 ps) UWB pulses at repetition rates from 10 to 40 MHz. Centered at a typical center frequency of 2 GHz, first-generation UWB typical system occupied 1.4 GHz. To avoid interfering with GPS signals and other low-power signals below 2 GHz, newer UWB systems, in compliance with Part 15 UWB requirements, now occupy 3.1 to 10.6 GHz. Because the pulses are pseudo-randomly (PN) shifted in time, transmitted signals resemble white noise to narrowband, conventional receivers. Because of their wideband characteristic, TM-UWB systems can co-exist with numerous other TM-UWB systems, as well as with existing narrowband communication systems, without causing significant interference. Likewise, because of their high processing gains of 30 dB or better due to occupying wide bandwidths, noise rejection performance of TM-UWB systems is superior to that seen in narrowband systems. Since the short duration pulses provide excellent multi-path immunity, the pronounced fades seen within buildings, or around a launch pad, with conventional narrowband systems are avoided; enhancing communication reliability of wireless LANs and other systems using UWB technology. In addition, because of the precise timing inherent from the time-modulated characteristics, precise position location functions are inherently features of UWB.

For a given range, limited mostly by peak powers, TM-UWB systems provide an especially attractive solution for portable, battery-powered applications. Because they employ pulses, the average power is extremely low (5 mW, or less), whereas the range associated with the systems is more like that seen for transmitter powers of 30 dB or so higher, as associated with their peak transmitter powers. In other words, a 5 mW average power signal is equal to 6.98 dBm; a peak power of 30 dB higher is equal to 36.98 dBm, or, in terms of Watts, 5 Watts. So, for the battery drain associated with a 5 mW transmitter, the effective range for a TM-UWB system is more like that of a 5 Watt transmitter. Put another way, whereas a cell phone might have 90 minutes of talk time on a typical battery, if TM-UWB technology were used instead, talk time, *ceteris paribus*, would approach tens up to hundreds of hours for the same battery charge. Alternately, for a given talk-time, the size of the phone and the cost of the phone could be greatly reduced. Whereas battery technology is mature, and greatly increased battery capacity is not feasible with known battery chemistries, TM-UWB modulation could provide the equivalent effect of a disruptive technological breakthrough in battery technology with regards to body-worn, battery-powered communications gear.

In short, TM-UWB represents a major shift in terms of implementation capabilities. Further, because of battery life extensions, it is possible to tailor the battery-life to reduce the cost of existing batteries through eliminating materials. With all the benefits, as well as the cost reductions possible, TM-UWB technology is truly a disruptive technology.

The FCC authorized UWB transmission systems as of February 14, 2002, with their final report adopting the use of UWB technology. A commercial product is now available from Time-Domain, of Huntsville, AL, consisting of a pair of radios and an Ethernet link, along with controlling software to enable low-cost evaluation of their first generation UWB technology using standard LAN Ethernet technology. Likewise, XtremeSpectrum

of Vienna, VA, has announced a four-chip chipset providing 100 Mb/s data rates and consuming less than 200 mW costing only \$19.95 in quantities of 100,000.¹⁸⁴ XtremeSpectrum's chips are planned for use in wireless consumer products by Christmas 2003. UWB technology is just now becoming available for use in wireless devices to support future Spaceports and Ranges.

4.7.2 Historical Parallels of Ultra Wideband (UWB)

The last disruptive technology shift in wireless of a similar magnitude occurred during World War I. Early wireless signals (i.e., radio signals) were mostly transmitted from 1896 until 1919 with broadband spark-gap transmitters. Capitalizing on this spark-gap transmitter technology, and on his own successful 1896-1898 wireless experiments, Guglielmo Marconi obtained funding in 1899 to found the British Marconi Company. In 1901, he further expanded his company through opening an American subsidiary. With a successful demonstration of communication over the Atlantic Ocean from England to Newfoundland on December 12, 1901, the British Marconi Company became the dominant wireless company in the world. They remained dominant until 1919, when spark-gap radio was replaced with a more modern, disruptive technology.

Not all was rosy, however, even during the early years of the British Marconi Company's dominance. The existing trans-Atlantic cable companies and the telephone companies on both sides of the Atlantic were firmly entrenched, and applied considerable business pressure to counter the British Marconi Company's upstart technology. No upstart 'wireless' company would be allowed to threaten the dominant telecom businesses of the day. Because of political pressure from the existing Anglo-American Telephone Company, Marconi left Newfoundland and was forced to re-locate to Nova Scotia. Likewise, the international competition against more robust and established trans-Atlantic cable companies further squeezed Marconi's company through eliminating international trans-Atlantic communication business. The only remaining profitable niche was purely marine business – i.e., the ship-to-ship and the ship-to-shore communication businesses, where, for purely technical reasons, neither of the existing companies could compete; and it was in providing these services where the British Marconi Company found its home.

Spark-gap transmitter signals occupied multiple MHz of bandwidth in the course of sending information requiring 100 Hz or less bandwidth for transmission. Although wasteful of the RF spectrum, as long as spectral occupancy remained light, this approach provided more than enough success to interest even more users in attempting wireless communication. By about 1917, with increasing numbers of spark-gap transmitters attempting to transmit information over long distances, the result was pure bedlam. In an unsuccessful attempt simply to transmit over interfering signals, increasingly powerful transmitters and larger and larger antennas were tried. Transmit signal selectivity was

¹⁸⁴ Yoshida, Junko. *Startup bets chip set on ultrawideband home nets*. Electronic Engineering Times, June 24, 2002, p. 4.

initially determined only by the bandwidth of the antenna connected to the transmitter.¹⁸⁵ This was clearly not conducive to packing more users into the limited spectrum available, and circuit techniques to constrain the transmitted bandwidths even more, were developed during 1916-1919, i.e., the World War I era.

Through the introduction of narrowband, continuous-wave (CW) Morse Code Transmitters, the disruptive technology of narrow-band oscillators was also starting to have an impact. The British Marconi Company, however, felt that in its niche market the broader bandwidth inherent with a spark-gap transmitter was better to attract the attention of a radio operator aboard a nearby ship or ground station in the event of a catastrophe aboard a ship. CW transmitters, though, soon started breaking the communication distance records held by typical spark-gap transmitters. Meanwhile, the British Marconi Company stubbornly held on to its spark-gap transmitters, and, relative to the primitive state of lobbying Congressmen in that day, attempted to obtain protection against the replacement of its transmitters aboard ship. Still, the writing was on the wall. Spark-gap transmitters could not be used in a crowded environment, and more and more signals were coming on the air each day. In just a couple of years, over 1918 through 1919, the British Marconi Company quickly lost the title of being the dominant wireless company to the new Radio Corporation of America (RCA) formed in 1919. The British Marconi Company had started to lose its market share due to disruptive technology changes.

The British Marconi Company's plan for survival was concentration in a niche marine market, where spark-gap transmitters still had an edge. Capitalizing on bandwidth-reducing technology, in 1924 the U.S. government attempted to further reduce the cacophony of transmissions through limiting both the transmitter power and the operating frequency of spark-gap transmitters. When the new regulations went into effect, spark-gap transmitters suddenly lost most of their communication competitiveness, nearly overnight. Still, the number of new transmitters, both spark gap and CW increased. In 1927, the U.S. government finally banned all spark-gap transmitters, even aboard ships far at sea. The result was that the British Marconi Company became more of an historical footnote than a continuing leader of the wireless industry.

Whereas radio signals started as broadband signals occupying very wide bandwidths, the trend for many decades was increasingly to decrease bandwidths, while improving bandwidth efficiency. With the introduction of TM-UWB technology, the trade of bandwidth against power can again be re-evaluated, with the result that broadband signals once again represent a significant promise of creating new possibilities, and new opportunities for those companies willing to invest in the new technology.

Similarly, today's existing wireless companies risk becoming the modern-day equivalent of the British Marconi Company of 1927; surpassed by startup companies willing to develop TM-UWB products and market them. For existing companies, to fight the introduction of TM-UWB products through lobbying is very much like the attempts in

¹⁸⁵ This was also the case for the first generation UWB transmitters, developed in the 1980's.

the early 1920's to legislate the required use of spark-gap transmitters onboard ships to insure the maximum likelihood of attracting the attention of nearby radio operators in the event of a disaster. Legislation then only delayed the inevitable and the British Marconi Company fell in importance in 1927, whereas, from 1901 through 1919 it had been THE dominant wireless company. The lessons of history are often forgotten in technology circles, much to the financial detriment of those companies, investors, and even individuals that forget the lessons. Instead of sending lobbyists to Washington to ban its use, wireless technology companies of today should instead become engaged in R&D to improve their understanding of UWB. The genie is already out of the bottle. It is better to profit from UWB technology than to try belatedly to ban its use. In the end, individual consumers and the marketplace in general will be the ultimate winners.

4.8 GLOBAL POSITIONING SATELLITES

4.8.1 GPS

On the night of August 31, 1983/September 1, 1983, a Korean Airlines civilian Boeing 747, Flight KAL007, inadvertently flew over, or near, the Kamchatka Peninsula and Sakhalin Island, both of which were then highly protected Soviet military areas. In response to this over flight, Flight KAL007 was shot down by the Soviet Air Force, resulting in the death of over three hundred passengers and crewmembers, most of which were civilians. Amid the subsequent worldwide condemnation of the shoot down decision by the Soviets, a decision was made by then President Reagan, and by the US Congress, to prevent the future recurrence of such civilian tragedies. Their decision was to open the US Military's Global Positioning System (GPS) for use by civilian users worldwide, to prevent the future recurrences of such tragic errors in navigation. Originally developed for the precise navigation of military aircraft and weapons systems, and freely available since the shoot down of KAL007 in 1983 for civil use, the US Global Positioning System is comprised of three main segments. These three segments are the Control, Space, and User Segments.

The Control Segment is managed from the Master Control facility located at Schriever Air Force Base (formerly Falcon AFB) in Colorado. Monitoring stations within the Control Segment, located in Hawaii, Ascension Island, Diego Garcia, Kwajalein, and Schriever AFB in Colorado, measure signals from the GPS satellites, generally referred to as Space Vehicles (SVs) (Figure 4-1). Data taken from these SVs are then processed and incorporated into orbital predictive models for each of the satellites. The orbital models generate precise orbital data (ephemeris) and SV clock corrections for each satellite. The Master Control station in Colorado then uploads both ephemeris and clock data to the SVs.

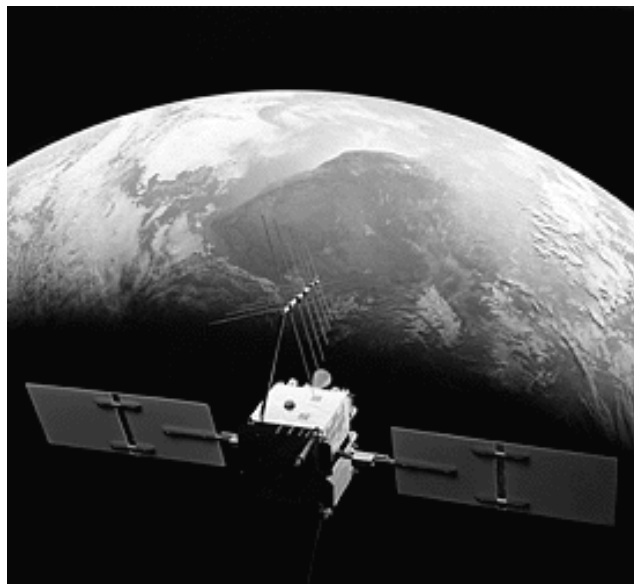


Figure 4-1 GPS Satellite

The Space Segment consists of the nominal 24-satellite constellation of SVs, each of which orbits the Earth every 12-hours. Orbital ground tracks of individual SVs repeat (as the Earth turns beneath them) once each day, returning over the same point on Earth approximately every 23 hours, 56 minutes. SVs are arranged in six orbital planes (with nominally four SVs contained in each plane), equally spaced around the Earth (i.e., at 60 degrees separation). The individual orbital planes are inclined at about fifty-five degrees with respect to the equatorial plane, thereby providing users with between five and eight SVs visible from any point on Earth. To provide readily available backups in the event of a failure of one of the active SVs, generally, at least two spare SVs are kept in orbit, thereby providing a typical total constellation of 26-satellites, or more, on orbit.

The User Segment is comprised of the GPS receivers and all the users that use GPS for obtaining precise position and velocity navigation as well as for time information. To provide an acceptable position fix, four satellites (minimum) are required within view of each user to compute the four dimensions of X, Y, Z (i.e., 3-Dimensional position) and Time (i.e., the 4th-Dimension). Furthermore, to provide as accurate information as possible, typically one to three additional SVs are needed, to insure that spatial geometries of the apparent positions of SVs from any point on Earth are adequate for generating good position solutions, avoiding Dilution of Precision (DOP) that would otherwise occur due to bad spacings/locations of SVs relative to any specific point on Earth. GPS receivers convert SV signals into position, velocity, and time estimates.

GPS position accuracies vary, depending on the GPS code used by the GPS receiver. Typically, the two-dimensional positional accuracy provided by GPS C/A-code is around 10 meters, whereas P (Y)-code provides two-dimensional position accuracies generally to less than 5 meters. Because of the high positional accuracy provided even by C/A-code, the Department of Defense (DoD) originally used SA (Selective Availability) to dither the short-term accuracy, to prevent enemy missiles from using GPS signals to target fixed, hardened targets, such as ICBM missile silos. With SA code, typical two-dimensional position accuracies were degraded to around ± 100 meters (95% horizontal accuracy). Due to the growing dependence of civilian aircraft and systems on GPS, and to the lessening worldwide threat of nuclear ICBM attacks, SA code was permanently deactivated on May 2, 2000 by order of President Clinton. Through using two commercial receivers, P-code, originally available only to military receivers, is also essentially available for special civilian purposes such as surveying. Even if P-code is derived using two commercial receivers, Spoofing (discussed later) can still cause significant errors, and further safeguards must be used to overcome the threat imposed by spoofing whenever using P-code.

GPS signals, broadcast from the SVs to GPS receivers, are transmitted over spread spectrum radio signals at the Link 1 (L1) and Link 2 (L2) frequencies centered at 1575.42 MHz and 1227.60 MHz, respectively. Most civilian receivers only receive on L1. At present, most military receivers must receive on L1 to acquire GPS, but often then switch to L2 for GPS tracking. GPS link margins for many receivers are typically only 3 to 4 dB, meaning that GPS is largely useless within buildings, or even under wet canopies of leaves in the fall along many city streets. Because of the low power levels (i.e., around

10^{-16} Watts at the Earth's surface), and wide bandwidths in excess of 24 MHz, susceptibility to jamming is also a threat, whether intentional or unintentional. Harmonics of several UHF TV channels in the United States are notorious for causing what some have termed GPS 'wormholes', i.e., geographic areas in which GPS is unavailable. Specific TV channels especially known to cause frequent jamming problems are channels 66 (2nd Harmonic), and 23 (3rd Harmonic). In addition, smaller 'wormholes' also exist around TV towers broadcasting on channels 5, 6, 7, and 10, which often have higher order harmonics, ranging from the 8th Harmonic through the 20th Harmonic, that fall inband to the GPS bands. Due to their lower typical transmitting powers, and higher order harmonics necessary for harmonics to fall within the GPS bands, FM radio stations have even been known to cause GPS jamming problems, too; although typically over much smaller geographic areas.

Susceptibility to GPS jamming varies among various GPS receivers. Surprisingly, during initial acquisition, civilian receivers often are more resistant to jamming than military receivers. This comes about due to the relative bandwidths of the coded signals involved. The GPS C/A (Coarse Acquisition) code is broadcast over L1. It is a narrowband signal required to obtain a precise time offset into the PN code known as P-code (Precise Code). The GPS P-code, as originally envisioned, was only used by military receivers to obtain precise location information. It is a wider bandwidth PN sequence, having a longer sequence before repeating. Because of the difference in bandwidths, and the need to keep costs low, civilian receivers typically have a very narrow RF front-end bandpass filter at the input to the receiver, to permit the use of a lower-cost, lower-performance Low Noise Amplifier (LNA) at the receiver input. Military receivers, having to operate with P-code, typically have much wider RF front-end bandpass filters. With the wider bandwidth required to receive P-code, their total equivalent input noise power, consisting of the integrated noise power spectral density due to thermal noise over the input passband, forces the selection of higher-cost, lower noise figure, LNAs in military receivers to maintain sensitivity comparable to sensitivities of civilian receivers. The unintended side effect is that military receivers are more susceptible to jamming, whether intentional or otherwise, during acquisition than civilian receivers because of their wider RF front-end filters. Once GPS is acquired, though, military receivers operating at L2 often have higher anti-jam performance than civilian receivers operating at L1, due to the processing gain provided by the P-code that spreads the power of the (presumably) narrowband jammer over wider bandwidths than C/A-code does in the process of GPS code de-spreading. The solution for military receivers to acquire GPS is relatively simple, though. They simply acquire GPS outside the area where jammers are present.

How real is the threat to GPS receivers from terrorist jamming? Unfortunately, it is severe. Several studies have consistently shown that a one-watt jammer can easily 'take out' GPS over wide areas, out to a radius of well over 50 miles from the jammer. Furthermore, experiments have been done whereby an effective jammer was built in a package the size of a standard soft-drink aluminum can, using low-cost parts available from a local Radio Shack store, for under \$50. Likewise, a 400-watt jammer, operating at an altitude of 10,000 feet at Ft. Bragg, NC, for example, *affected* civilian GPS receivers out to even the neighboring states of Virginia, and South Carolina, while

denying GPS operation to civilian receivers over approximately 1/3rd of North Carolina.¹⁸⁶ Battery-powered jammers, constructed inexpensively, could, in a worst-case scenario, be airdropped over a wide area, effectively denying GPS for days around a Spaceport, or on a Range, before exhausting self-contained battery power.

Hardening GPS receivers against jammers, though, is not entirely possible using P-code processing alone. Processing gains, after all, are limited, and this limits the degree of anti-jam (AJ) protection that can be achieved through processing gain alone. The solution is to add additional AJ performance through spatial selectivity. This can be accomplished using phased array antennas.

The basic decision that must be made in choosing a phased array antenna to provide AJ protection is to decide on the number of diverse directions in which jammers can be considered to exist simultaneously, and which must be nulled. This number of diverse directions equates to what is called the number of Degrees of Freedom (DOF) required to provide AJ protection. A typical Controlled Radiation Pattern Antenna (CRPA, pronounced as ‘serpa’), used to provide AJ GPS performance, provides nulling performance of either 3-DOF or 4-DOF. Relative to the number of antenna elements required to provide a specified number of DOF performance, the basic assumption is that one of the elements becomes the reference element. The remaining elements, combining against the reference element in a destructive interference fashion, then determine the DOF performance. In other words, the number of elements required for an AJ GPS Phased Array antenna is one more than the Degrees of Freedom performance desired. Hence, a four-element array can null up to three jammers that exist in diverse spatial separations.¹⁸⁷

To achieve the destructive interference required along the lines of bearing, or look angles, at which jammers exist, the elements in an AJ GPS phased array must be adjusted in terms of the weighting applied to each antenna element output signal. This can be accomplished by using either phase shifters or complex weights. Using phase shifters, however, limits the ability to adjust the amplitude weighting, which is needed to account for partial masking of the reference element, which can occur at certain look angles from the reference element. The result is that purely phase-shifted phased arrays provide limited AJ nulling performance, and are usually not used; except in the most inexpensive or lowest power consumption systems.

A preferred approach is to use four-quadrant complex weights, which provide full X-Y control through a combination of amplitude and phase shifting functions. A typical RF Complex Weight provides in excess of 50 dB of dynamic range, over the full 360° range

¹⁸⁶ Williams, Drew. *GPS Vulnerability*. GPS Users Conference, SPAWAR System Center San Diego, 02 November 2000. (LCDR Drew Williams, SSC-SD, Code D315, GPS Division)

¹⁸⁷ Likewise, a theoretically infinite number of jammers along a single spatial direction vector can be nulled with a single element when operated against a reference element. One element equates to nulling one jammer against a reference element only when the jammers are in diverse spatial orientations.

of angles. In turn, such an RF Complex Weight can provide nulls against jammers in excess of 50 dB. The primary performance requirements for RF Complex Weights are:

- Monotonicity, whereby no two X-Y states can have the same input conditions separated by a higher-energy state (otherwise, stable algorithm control is lost)
- Orthogonality, whereby the X and Y-axis commanded states cannot overlap – i.e., when commanding, say at equal X and Y states, the goal is to be as close to a line with a slope of one as possible; otherwise, the effect of a change in the state of the X-axis setting affects the Y-axis setting, and vice versa, preventing stable algorithm control
- Dynamic range, whereby the number of bits of control integral within an RF Complex weight digital to analog converters exhibits both resolution as well as true dynamic range, permitting the setting of precise positions in the complex X-Y space, as needed for setting deep nulls
- Response speed, whereby the RF Complex Weight can be commanded quickly to a new state (this is mostly a requirement on the Digital to Analog converter within the RF Complex Weight, determined by both choice of semiconductor technology and by power consumption)
- Power consumption (with the goal of limiting the heat that is dissipated, or which must be dissipated)

The antenna element weighting algorithms, used to set the exact settings within the RF Complex Weights on each element's output, vary depending on vendor, although many older algorithms are in the public domain. In general, the desire is to achieve AJ solutions within less than one hundred milliseconds, and typical microprocessors have long been capable of finding and updating AJ solutions in but a small fraction of this time frame.

During the early 1980's, AJ GPS phased array antenna systems occupied racks of equipment, and typically had associated costs in the multiple millions of dollars, each. By the late 1980's, with the development of low recurring-cost Gallium Arsenide (GaAs) and Silicon (Si) RF Complex Weights fabricated on single integrated circuits, the price and physical volumes dropped dramatically. In high volume applications, recurring costs under a hundred dollars per AJ GPS phased array antenna, including digital controller and RF circuitry, became possible, contained within volumes measured in but a few cubic inches.¹⁸⁸ With this reduction in volume and cost, the availability of AJ GPS phased array antenna appliquéés became possible for use on handheld GPS Receivers. Likewise, it became possible to add AJ GPS even to smart bombs, comprised of World War II and

¹⁸⁸ The limit on physical size is now mostly determined by the physical spacing required to keep the antenna elements in the phased array from becoming over coupled. At the L-Band frequencies used by GPS signals, the need for roughly ½-wavelength spacing between elements, to limit element-to-element coupling, sets the lower bound on a small phased array for AJ GPS use to around four or five inches long and a couple of inches wide with a 3-DOF system. The depth is mostly determined by the internal electronics behind the GPS phased array antenna elements. Higher DOF performances, and deeper nulling requirements, often push the physical volume higher.

Korean War vintage designs of dumb 500 lb and 2000 lb gravity bombs with strap-on, small control surface modules. These smart bombs, directed by GPS control, are capable of providing highly-accurate GPS-assisted targeting of fixed ground assets in mostly shoot and scoot scenarios, or, more accurately, lob toss and run, missions. After all, bridges and other fixed targets cannot run away when under attack.

In addition to being susceptible to jammers, civilian GPS receivers are also susceptible to C/A-Code Signal Spoofing. Spoofing is the sending of intentionally deceptive fake GPS signals to prevent receivers from deriving accurate position and velocity information. Once tracking Y-code, military receivers are inherently spoof-resistant. To understand the difference between Y-code and P-code, it is necessary to realize that the DoD has historically used two techniques to encode GPS signals and deny the full accuracy of GPS to unauthorized users: Selective Availability (SA) and Anti-Spoofing (AS). With SA, the DoD dithered the time broadcast by each satellite and could introduce intentional errors into the broadcast ephemeris. This resulted in a range error measured by (civilian) GPS receivers, resulting in a non-deterministic position error. As discussed previously, due to the growing dependence of civilian aircraft and systems on GPS, and to the lessening worldwide threat of nuclear ICBM attacks, SA code was deactivated on May 2, 2000. AS, on the other hand, is still used. When AS is activated, P-code is encrypted, creating Y-code, which prevents an appropriately designed military GPS receiver from being fooled by an intentionally deceptive fake GPS signal. Y-code is simply encrypted P-code. A military receiver must have a valid cryptographic key to enable the ability to remove the effects of SA (when it was used) and to use Y code.¹⁸⁹

Modernization plans for GPS include introducing a third carrier, known as L5, centered at a frequency of 1176.45 MHz carrying M-code (Military-code). Likewise, there are plans to add M-code additions on both the L1 and L2 frequencies. (M-code is intended for Civil Safety of Life Applications and New Military Applications.) In addition, to address the problems associated with every present military receiver having to acquire C/A-code on L1, there are plans to add C/A-code on L2, as well. In this way, increased flexibility will be provided, increasing the ability of future military receivers to overcome non-intentional jamming during acquisition. As part of the GPS-III Systems Architecture and Requirements Definition (SARD) phase, the 12-month contracts to complete these modernization plans were awarded on November 9, 2000 to Boeing and Lockheed Martin. Likewise, the modification letters were sent out in August 2000 for implementing changes to the Block IIR and Block IIF SVs to perform the necessary modification to unlaunched SVs. IOC (Initial Operational Capability) will occur over FY06 to FY08 for M-code and L5 additions. High-power M-code will occur on the first of the GPS-III SVs planned in about FY09. GPS-III SVs are planned to carry the bulk of the GPS workload out to 2030, which is the same date out to which the Advanced Range Technology Working Group (ARTWG) (and SBRDSWG) are likewise focusing.

¹⁸⁹ *GPS Q&A*, Earth Observation Magazine, January 1996, <http://www.eomonline.com/Common/Archives/Jan96/gps.htm> retrieved 16 July 2002.

4.8.2 TGRS

TGRS (Translated Global Position System Range System) began as a USAF project providing engineering, development, and initial test sets of time-space-position information (TSPI) instrumentation primarily to provide range safety and weapon system testers with accurate position data during all phases of missile launch and flight. Based on Global Positioning System (GPS) technology, TGRS hardware is intended to meet joint Service requirements for providing precise TSPI. The major portions of the TGRS instrumentation are an airborne Digital GPS Translator (DGT) and a ground-based GPS Translator Processor (GTP). The DGT provides an extremely compact and accurate range capability module for installation on strategic and tactical missiles and spacecraft vehicles. The GTP, on the other hand, incorporates position information from all-satellites-in-view, with minimal data latency, as needed to track fast moving vehicles at up to 75g dynamics from the ground.¹⁹⁰

To date, TGRS instrumentation is being used to replace the Flight Test Support System at Jonathan Dickinson Missile Tracking Annex (JDMTA) located at the Jonathan Dickinson State Park, Florida, as part of an ongoing \$103.8M upgrade to the Eastern Range facilities by Computer Sciences Raytheon. This work was started in 2000, with the bulk of the change-out occurring in 2001 and 2002.¹⁹¹ Presently (May 2002), TGRS instrumentation is being used to provide TSPI for range safety for the routine launching of Naval missiles from the Eastern Range.

4.9 DATA ASSURANCE

Achieving data assurance for a range information system network requires understanding many computer-based information topics. Considering just the major topics, data assurance for this network must include provisions for achieving:

- Data Integrity (i.e., protection against tampering, whether intentional or unintentional)
- Data Authentication (i.e., anti-spoofing functionality)
- Data Availability (which can range from minor latency issues [timeliness] all the way to data unavailability)
- Data Ease-of-use
- Data Security (i.e., protection of data content from access by unauthorized personnel)

¹⁹⁰ <http://www.acq.osd.mil/te/programs/cteip/af.html>

¹⁹¹ <https://www.patrick.af.mil/451g/45cons/contract/rtsc/downloads/contract/mods/P00030.pdf>

Data assurance also involves maintaining the operational computer-based data system, itself, to guarantee the timely delivery of data when needed, both in real-time and when retrieved later. Of course, this requires mundane preventive maintenance. Further, this identifies a need for including information management features for range information data archival (data backup) functionality along with data recovery and retrieval administration in future range information systems.

Each of these areas, involving Data, the range information system infrastructure, and the paradigms for storing and retrieving information, must be individually addressed to achieve the level of Data Assurance required for the data created, used, and archived on future Spaceports and Ranges. Fundamentally, Data Assurance must become more than a metaphor for simply achieving good infrastructure plumbing to pipe information quickly and without loss around future spaceports and ranges. Additionally, data assurance must provide an infrastructure capable of establishing a commons for data, a virtual meeting place, where both humans and computers go (in a virtual sense), for all the information required to accomplish the business of accessing space. This must be done while simultaneously creating a culture for seamlessly supporting the flow of information needed for achieving routine access to space; along with paying, whenever possible, considerable attention to providing a pervasively wireless infrastructure. The following sections explore these data concepts in more detail.

4.9.1 Data Integrity

Data Integrity refers to protection against data tampering, whether intentional or unintentional. For a rather unlikely example, intentional data tampering could be the result of an attempt to hide telemetry data, after a catastrophic launch event, perhaps to prevent the disclosure of an error on the part of an individual or group of individuals. It could also be the result of unauthorized modification(s) of existing data, perhaps to support a different conclusion than would otherwise be inferred from these data. Each of these occurrences is unlikely, but to achieve true Data Integrity, they must be guarded against in the fundamental design phase of a future range information system. Unintentional tampering of data, on the other hand, is a more likely threat to guard against. Consider, for example, lossy data compression methods. These could clearly have the effect of tampering with transmitted or stored scientific payload data. Evaluation of any so-called lossless data compression techniques would need to be vetted completely prior to a determination that the data compression technique was truly lossless. This would need to occur during the original design phase of the range information system. Another possibility that must be prevented, or at least mitigated, is the accidental damage of an operating system file, due perhaps to power surges or power outages. Signature analysis of files would be one way to detect the tampering of data files, whether intentional or otherwise.

4.9.2 Data Authentication

Data Authentication refers to the ability to determine whether the source of a specific data packet or data stream was truly from the origination source claimed for it. This could be done through electronic signature techniques, by which it would be possible to verify the veracity of the source, although not necessarily the truthfulness of the source. The key to Data Authentication is to determine and vet the source, not the veracity, of the data.

4.9.3 Data Availability

Data Availability refers to the presence of data when it is desired, at a specific location. At one end of the scale, Data Availability could refer to simple transport delays in a range information system, and could be expressed as a data latency issue. For example, if a high definition digital TV data stream from an HDTV camera observing a launch fed its data through an assortment of conversion techniques, perhaps as needed to feed older analog input TVs, a launch vehicle could literally be already off the pad and climbing into the sky before the visible indication would be observable on older analog TVs that were at a remote location from the launch. Similarly, data routing through the Internet, without quality of signal (QoS) guaranteed, could likewise cause delays in receipt of data requiring timeliness.

At the other extreme, it would be possible to envision a scenario by which a non-redundant data path was broken, in which case no data would be available from the source.

Data availability is a critical determining factor in the technical design details of future range information system networks. To confirm whether Data Availability needs were being met, it is likely that regular autonomous testing of Data Response Times would be needed in a range information system network.

4.9.4 Data Ease-of-Use

Ease-of-use for range information system data, storing and retrieving data, ranges from smart data simplification, whereby information overload could be reduced to a level with which an individual can cope (perhaps through the use of fuselet agents, in the parlance of data fusion technology), all the way to simplification of complete launch vehicle preparation processes. Although computer interfaces are typically not thought to require ease-of-use, in reality, the necessity of achieving data latency requirements may very well require encapsulation of data into smaller logical packets, whereby it is possible to route data packets in place of giant data packets in order to achieve low throughput latencies as desired. This equates to Data Ease-of-Use for computer interfaces.

4.9.5 Data Security

Data Security consists fundamentally of controlling unauthorized access to the network and preventing the theft of data contained within the network. Subsequently, security, of

both the data and the system processing these data, must be based on fundamental characteristics of the entire system, and must be totally separate and removed from any attempt to maintain what is often called *security by obscurity*. Attempting to obtain security through using an elaborate, hidden, yet unsound, technical principle is doomed to fail against the efforts of evildoers. In our modern computer age it is simply no longer possible to follow the wise ancient advice of Sun Tzu, who wrote: “If a secret piece of news is divulged by a spy before the time is ripe, he must be put to death, together with the man to whom the secret was told.”¹⁹² A more humane way is simply to increase the robustness of data security techniques and protocols to prevent the unintended release of data.

For just one modern example of why security by obscurity is bad, consider the 1999 breaking of the Content Scrambling System (CSS) encryption method intended to prevent the illegal copying of movies released on DVDs. CSS encryption was originally intended to prevent reading data from a DVD unless an unencrypted 5-byte (40-bit) decryption key was made available.¹⁹³ Unfortunately, the fundamental encryption algorithm was fundamentally weak, security by obscurity could not protect the deciphering of many keys given just one compromised key, and, worst yet, one of the companies participating in the DVD player encryption technique actually had used an unencrypted key that was then placed on every DVD.¹⁹⁴ Once the algorithm was reverse engineered, neither deleting the one unencrypted key on future DVDs or issuing a legal decree that using such techniques was now illegal, could close the door and prevent access to DVD movies, as the knowledge horse was literally already out of the barn once the algorithm became known. Obscurity of the algorithm through protection of its inner workings ultimately failed to prevent it from being overcome. What are the lessons that can be learned from this data management fiasco?

- First, security by obscurity of a weak data protection algorithm is the wrong approach for engendering data assurance in a range information system exposed to public scrutiny; instead, a strong algorithm should be used that is capable of withstanding public scrutiny. Public exposure additionally serves the dual purpose of ferreting out relatively quickly any weaknesses that may exist, while proactively working to close any weakness to prevent further endangering data assurance.
- Second, the loss of any one key, encrypted or not, should (ideally) not compromise the entire data system.

¹⁹² Sun Tzu, *The Art of War*.

¹⁹³ Although this is a short key by modern standards, 40-bit encryption was actually at the limit imposed at the time by the US Government on encryption techniques that could be exported. 40-bit keys were the maximum that were not export controlled.

¹⁹⁴ Andy Patrizio. *Why the DVD Hack was a Cinch*. *Wired News*. November 2, 1999. <http://www.wired.com/news/technology/0,1282,32263,00.html> retrieved 13 August 2002.

- Third, any data security system, assuming it is strong, should additionally use a strong cryptographic key to prevent the success of wholesale attacks against the key itself, given the full knowledge of the encryption/decryption machine.

With these three lessons learned from DVD decryption history, the fundamental attributes and ideas needed to achieve data assurance become intuitively obvious.

Yet, these ideas are not new. Rather, this fundamental approach for achieving security for data systems can largely be described using the six principles first identified by 19th Century linguist and cryptographer Auguste Kerckhoffs. Although Kerckhoffs first developed, and then applied, his six principles to military ciphers, their underlying characteristics and strengths apply to all data networking systems, not just to military ciphers or range information systems. These six principles, known variously as Kerckhoffs' Laws, Kerckhoffs' Assumptions, and Kerckhoffs's Principles, can be summarized as follows:¹⁹⁵

- 1° Le système doit être matériellement, sinon mathématiquement, indéchiffrable;*
- 2° Il faut qu'il n'exige pas le secret, et qu'il puisse sans inconvénient tomber entre les mains de l'ennemi ;*
- 3° La clef doit pouvoir en être communiquée et retenue sans le secours de notes écrites, et être changée ou modifiée au gré des correspondants;*
- 4° Il faut qu'il soit applicable à la correspondance télégraphique ;*
- 5° Il faut qu'il soit portatif, et que son maniement ou son fonctionnement n'exige pas le concours de plusieurs personnes;*
- 6° Enfin, il est nécessaire, vu les circonstances qui en commandent l'application, que le système soit d'un usage facile, ne demandant ni tension d'esprit, ni la connaissance d'une longue série de règles à observer.*

These principles, when translated into English, become:^{196,197}

- 1.1 The system must be practically, if not mathematically, undecipherable;
- 1.2 It must not be required to be secret, and it must be able to fall into the hands of the enemy without inconvenience (i.e., “The system must not require secrecy and can be stolen by the enemy without causing trouble;”);
- 1.3 Its key must be communicable and retainable without the help of written notes, and changeable or modifiable at the will of the correspondents (i.e., “It

¹⁹⁵ Auguste Kerckhoffs. *La cryptographie militaire*, Journal des sciences militaires, vol. IX, pp. 5-83, Jan. 1883, pp. 161-191, Feb. 1883. A 35 page pdf version of this famous paper is available on the web at http://www.cl.cam.ac.uk/~fapp2/kerckhoffs/crypto_militaire_1.pdf

¹⁹⁶ Wikipedia, The Free Encyclopedia. *Kerckhoffs Law*. <http://www.wikipedia.com/wiki/Kerckhoffs+law> retrieved 13 August 2002.

¹⁹⁷ <http://www.cl.cam.ac.uk/~fapp2/kerckhoffs/#english>

must be easy to communicate and remember the keys without requiring written notes, it must also be easy to change or modify the keys with different participants;”);

- 1.4 It must be applicable to telegraphic correspondence (i.e., in modern terms, it must be applicable to the telegraphic correspondence of the modern age, e.g. applicable to computer networking).
- 1.5 It must be portable, and its usage and function must not require the concurrence of many people (i.e., “The system must be portable, and its use must not require more than one person;”);
- 1.6 Finally, it is necessary, seeing the circumstances that the application commands, that the system be easy to use, requiring neither mental strain nor the knowledge of a long series of rules to observe (i.e., “Finally, regarding the circumstances in which such a system is applied, it must be easy to use and must neither require stress of mind nor the knowledge of a long series of rules.”).

In short, following Kerckhoff’s recommendations, any system claiming to provide data assurance through security techniques must be capable of withstanding public scrutiny during development, be easy to use, and must additionally employ an undecipherable (strong) key to provide a full defense against unintentional exposure of plaintext data or unencrypted keys. Otherwise, the system would likely not achieve the goals for which it was intended.

Modern mathematics provides the best method of assuring robustness of cryptographic techniques. Robustness, though, is not just about increasing complexity and making complexity integral to the algorithms and keys used. As but one example of the failure of complexity alone to provide adequate protection, Phil Zimmerman, creator of the excellent public-key cryptography system known as PGP (Pretty Good Privacy), created an earlier failed encryption system known as the BassOmatic. (The BassOmatic encryption algorithm was named in honor of a popular Saturday Night Live skit from late night TV in America that involved dropping a fish (a bass) into a blender; hence, the brand of blender in the fictitious commercial of the skit was “BassOmatic”.) Although Zimmerman’s BassOmatic encryption algorithm ‘chopped’ incoming data into very small pieces in a lengthy and complicated process, which could then be reversed to decrypt the ‘encrypted’ data, the algorithm provided very little protection against decryption. BassOmatic was rendered unacceptable for its intended purpose after a less than ten-minute review by an industry expert, at which point Zimmerman experienced an epiphany that led to the development of what became PGP. Robustness does not necessarily follow from complexity in devising cryptographic systems.

The lesson to be taken from this is that complexity is no panacea for protecting data, not even if one depends on security by obscurity to protect the complexity. The true key to achieving data assurance on range information systems is to use robust algorithms within a framework of algorithm openness, and then to use cryptographically strong (i.e., long) keys. Short cryptographic keys, poor algorithms (even if hidden), and un-scrutinized data handling processes are a recipe for failure, and should be avoided. Data Security, as

needed to support future Spaceports and Ranges, must depend on robust (not necessarily overly complex) algorithms that have undergone a considerable public peer review process, and which are fundamentally dependant on the use of strong cryptographic keys instead of depending on a false sense of security by obscurity.

4.10 VOICE OVER IP (VOIP)

Upon installing broadband connectivity, alternative implementations of conventional services immediately become possible. A prime example is Voice over IP (VoIP) technology, which upsets the traditional methods for exploiting technology to which many are accustomed. For example, consider the conventional paradigm, whereby low-bandwidth Internet services are obtained over conventional, dial-up, analog phone lines.

With VoIP, this paradigm is flipped; and instead one uses a high speed Internet connection, obtained through either a DSL or a Cable Modem connection to the Internet, to obtain local, instate, and state-to-state telephone services over the Internet. The introduction of 24/7, high-speed Ethernet connectivity is what enables a clear reversal of traditional technology roles.

The risk of adopting new technology early, in such a paradigm shift, before it is fully developed, is that it may not work well. A common outcome is that the most desirable features demonstrated by a new technology may be little more than technological stunts, working but poorly. Borrowing a Samuel Johnson expression, new, ill-performing technology is much “...like a dog’s walking on his hind legs. It is not done well; but you are surprised to find it done at all.”¹⁹⁸

In many ways, the initial protocol for VoIP, known as H.323, and established by the ITU, is and was such a dog, walking awkwardly on its’ hind legs. This arose because VoIP technology first grew out of video conferencing techniques developed for use over a Local Area Network (LAN) under a ‘define everything first, in a rigid framework, even if it might not be needed’ philosophy. H.323’s mostly unused overhead leaves much to be desired, in that:

- Addressing does not scale well, as H.323 cannot support URLs.
- There are possibilities of delays of up to 7 or 8 seconds for initiating, manipulating, and tearing-down VoIP sessions.
- Binary formats, not easily transportable across IP networks, are used in H.323.

¹⁹⁸ John Bartlett. Familiar Quotations. 10th Edition, 1919. Samuel Johnson (1708-1784) In full context, the quote was: “Sir, a woman preaching *is like a dog’s walking on his hind legs. It is not done well; but you are surprised to find it done at all.*”

- Voice-only traffic is permitted by H.323, whereas adding extensions to support transporting other traffic types requires adding non-standard, vendor-specific, modifications to the basic H.323 protocol.
- H.323 is built around a vertical philosophy concept, which means everything is included in H.323 (i.e., details regarding codecs, terminals, gateways, gatekeepers, and all other features). This increases the complexity, cost, and scope of providing VoIP capability.

Even as recently as early 2000, VoIP traffic initiated, manipulated, and torn-down using the H.323 suite of protocols was still a notoriously poor quality substitute for conventional telephone service; providing service that was poorer in audio quality and convenience than both conventional wired and current cell phone service. H.323 may be a suite of well-defined protocols, but the protocols are both cumbersome and inflexible, thereby precluding adding new features. For a young industry such as VoIP, such an approach, to define everything first and let technologists sort out the deficiencies later, often prevents fixing the very shortcomings that must be remedied to improve performance.¹⁹⁹ It is better to define a minimalist approach that is more easily adaptable, containing the inherent flexibility needed to accommodate changes to fix problems as they arise.

Within the last six months, with the large-scale adoption of the emerging standard Session Initiation Protocol (SIP) in place of the older H.323 legacy suite of protocols, the sorely needed flexibility lacking in H.323 has been achieved.²⁰⁰ The outcome, from switching to SIP in place of H.323, has been that VoIP technology has greatly improved quickly so that it now provides better audio quality, on average, than typical cell phone service. Current VoIP service is nearly indistinguishable from conventional wired telephone service. Relative to the earlier, less capable H.323 VoIP protocols, SIP provides unsurpassed high-speed Internet phone service without monopolizing a high-speed Internet connection. SIP is a low percentage bandwidth user of a broadband Internet connection. Instead of trying to contain all Internet functionality internally, it uses a scalable hierarchical URL style-addressing scheme and builds on existing Internet protocols, such as URLs, MIME formats, and DNS resolutions. SIP is developed around a horizontal, simple philosophy, and provides an application level protocol for establishing, manipulating, and tearing down connections transporting voice over existing Internet protocols. It starts with the same basic design philosophy as employed within C Programming and Unix environment circles, of building modular components that do but one function well. Because of this fundamental, simplistic, minimalist design decision, SIP messages are text, instead of binary; thereby enabling them to be passed

¹⁹⁹ <http://www.sipcenter.com/aboutsip/siph323/h323sip.htm>

²⁰⁰ SIP is being driven not from within the ITU like H.323, but from within the IETF (Internet Engineering Task Force). The IETF is inherently pro-Internet, desiring to build on what has already been achieved in the Internet world. For more information, see the IETF's website: <http://www.ietf.org/>, especially the SIP related information section at: <http://www.ietf.org/html.charters/simple-charter.html>.

quickly through various types of networks while quickly setting up connections. Additionally, because of the underlying simplicity, SIP is able to seamlessly interact with media types other than voice, while achieving a minimal delay much smaller than the 7 or 8 seconds typically seen in H.323 networking. Although SIP contains no QoS (Quality of Signal) provisions in its defined protocol, in practice, the low overhead and fast throughput inherent with SIP sessions do allow achieving high QoS. Because the simple, horizontal philosophy approach within SIP reduces complexity, the VoIP costs associated with managing SIP sessions are extremely low; relative to the costs of managing H.323 sessions.

How is VoIP user equipment currently installed? For the typical user, it is but a simple add-on to an existing high-speed Ethernet LAN. As shown in Figure 4-2, an Analog Phone Adaptor is simply plugged into a broadband Ethernet connection, and a conventional telephone is then plugged into the Analog Phone Adaptor. Unlike in early VoIP systems, no dedicated computer running custom software is required to receive unplanned or unexpected telephone calls. As shown in the setup diagram, a router with an integral Ethernet Switch output provides the necessary outputs needed for sharing a high speed Internet connection between an existing computer and the Analog Phone Adapter for the VoIP phone.

The leading provider of VoIP service (as of August 2002) is Vonage, of Edison, NJ.²⁰¹ Following the same basic setup shown in Figure 4-2, customers simply subscribe to Vonage's VoIP service, connect an Analog Phone Adaptor to their broadband Internet Ethernet connection, and then plug in any conventional telephone to the Analog Phone Adaptor. Using a VoIP telephone is then as easy as picking up a conventional phone, listening for the dial tone, and dialing the desired phone number (along with the desired area code if the destination is outside the area code chosen for the VoIP phone number, which is *not* necessarily the same area code in which the VoIP phone is physically installed). There are no extra access numbers to be dialed, as required with long distance calling cards, nor are there any long distance fees charged for calls made to phone numbers registered within the United States.²⁰² Additionally, it is possible to pick any of several popular area codes for the VoIP phone, thereby creating an easily implemented virtual presence in any of several major population areas within the US.²⁰³ This option

²⁰¹ Vonage home page, <http://www.vonage.com/index.php>, retrieved 29 August 2002.

²⁰² It would be possible to have two VoIP phones located in separate countries, but with both VoIP phones having stateside area codes assigned through signing up for VoIP service with Vonage. It would then be possible to call toll free between these two VoIP phones located in separate countries. All that would be required would be high speed Internet connectivity in each country for accessing the Vonage network. Additionally, any two phones with Vonage VoIP service likewise have free unlimited connectivity between them available.

²⁰³ As of August 2002, phone numbers from all of the following US area codes are available for assignment to new Vonage VoIP phones, irregardless of the physical location of the VoIP phone:
CA: 213, 310, 323, 408, 415, 510, 562, 626, 650, 661, 707, 714, 760, 805, 818, 831, 909, 925, 949;
FL: 305, 561, 786, 954;
GA: 404, 678, 706;

additionally works from anywhere in the world; thereby allowing, for instance, an Internet user in Europe or Asia, or anywhere else in the world with a high speed connection, to call toll free throughout the United States from overseas. In the reverse direction, conventional PSTN (Public Standard Telephone Network) calls to a VoIP phone are indistinguishable from calls made to any other phone; specialized VoIP equipment is only required by the user subscribing to the Vonage VoIP service.

Pricing for Vonage VoIP service depends on the service plan offered. For unlimited US local and long distance (in state and state-to-state) service, the price is \$39.00 per month, which includes a free Cisco ATA-186 Analog Phone Adaptor. For users requiring less service, there is a lower priced service option priced at \$19.99 per month, that provides up to 500 minutes of local and long distance service, again with a free Analog Phone Adaptor. International calls placed through the Vonage VoIP network incur additional costs, ranging from approximately 5 cents per minute for calling the UK, Japan, Canada, and other high bandwidth wired areas of the world, up to a high of 91 cents per minute for calls made to remote, non-Internet wired areas, such as Afghanistan.

The only drawbacks to the VoIP service at present are that international calls to phones outside the United States can be pricey, depending on the destination country's support of high speed Internet connectivity, and emergency 911 type calls are not yet supported, although there are plans to resolve the 911 issue within the 2002-2003 time frame.

In terms of supporting remote, down-range, tracking stations with high speed Internet connectivity, VoIP service through companies such as Vonage can provide a very low-cost way to make in state and state-to-state calls back stateside. As such, VoIP technology seems destined for future use on and between future Spaceports and Range assets.

IL: 312, 630, 708, 773, 815, 847;
IN: 219;
MA: 508, 617, 781, 978;
NJ: 201, 732, 908, 973;
NY: 212, 347, 516, 631, 646, 718, 845, 914, and 917.

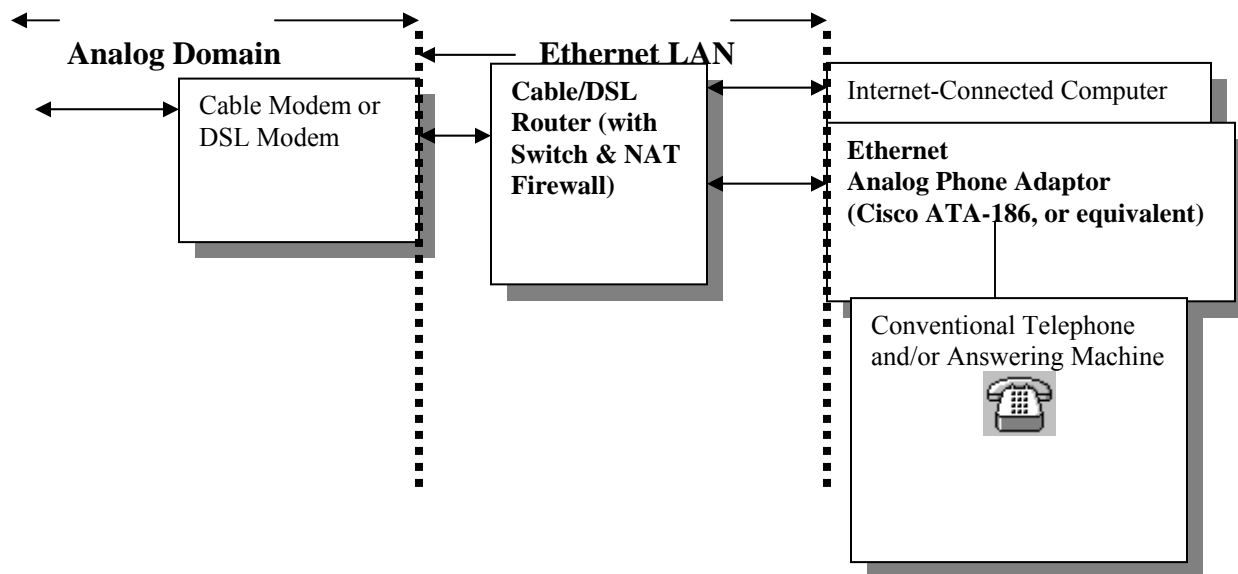


Figure 4-2 Installing VoIP Telephone to a Broadband Internet Connection

5.0 FUTURE LAUNCH VEHICLES

Future Ranges and Spaceports will be heavily dependent on advanced launch vehicles being utilized by the commercial sector. This section will discuss:

- Future vehicle concepts
- Additional Concepts that explore the matrix of almost all rocket concepts and that further identify non-rocket launch concepts.

The first category includes the second generation of the Shuttle, the X-Prize concepts, Space Tugs and the Trans Atmospheric Vehicle (TAV).

The second category includes the generic launch vehicle matrix plus more advanced concepts such as Railgun, Space Cannons and Space Elevator; which are likely to be implemented, if at all, in the more distant future.

Because of the inherent dependence of Future Ranges and Spaceports on the fundamental characteristics of the launch vehicles, a clearer understanding of the varied possible launch vehicles is required for a complete view of their likely impacts.

5.1 **2ND GENERATION RLV (NRA 8-30)**

Bold new starts in the developments of US space launch systems and vehicles occur only infrequently. For example,

- August 15, 1958 marked the start of the Saturn Program, which developed the boosters used to put man on the moon on July 20, 1969, not quite eleven years later.
- January 12, 1972 marked the start of the 1st Generation of Reusable Launch Vehicles, resulting in Columbia (OV-102), the first of NASA's orbiter fleet, being delivered to Kennedy Space Center in March 1979. Columbia initiated the Space Shuttle flight program when it lifted off Pad A in the Launch Complex 39 area at KSC on April 12, 1981, just over nine years after the formal start of the Shuttle program.
- October 12, 2000 marked the start of the 2nd Generation Reusable Launch Vehicle (RLV) Program, planned for development by 2005, only five years after the start of this program.

The 2nd Generation RLV Program was formally commenced upon the issuance of the NASA Research Announcement (NRA) 8-30 Request for Proposal (RFP) on October 12, 2000. NRA 8-30 defines two cycles of activities for the 2nd Generation RLV Systems Engineering and Risk Reduction activity. Through the accomplishment of these two cycles of activities, it enables full-scale development of commercially-competitive,

privately-owned and operated Earth to Orbit (ETO) RLVs; and develops an integrated architecture with systems that build on commercial ETO launch vehicles to meet NASA-unique requirements that cannot be economically served by commercial vehicles alone.

Total NRA 8-30 funding is \$900 Million, with approximate budgets of \$150 Million in fiscal year 2001 (FY-01), \$230 Million in FY-02, and \$520 Million in FY-03 through FY-05. As a cost comparison, this five-year expenditure amounts to roughly 1/3rd of NASA's current annual space shuttle program cost, which, for six to eight, launches, is approximately \$3 billion per year.²⁰⁴ In terms of historical cost comparisons, the total estimated cost of the Saturn Program, when made in 1960, was \$8 billion (in 1961 dollars) for up to 1975.²⁰⁵ Actual costs through the development phase, up to Apollo 4, totaled \$616 Million.²⁰⁶ Relative to the actual development costs for the Saturn Program and to actual current annual Shuttle Program costs, the program cost savings anticipated by incorporating privately-owned and operated approaches in NRA 8-30, in place of using solely government-owned and operated ETO launch vehicles, is obvious. It is even more remarkable when compared in terms of constant dollars. The reduction in the number of years required for development of each subsequent system is likewise noteworthy. The time to develop each successive program is significantly reduced through incorporation of increasingly powerful computer analysis tools, thereby reducing design cycles; as well as through re-use of knowledge previously learned.

Coordinated through the Space Launch Initiative (SLI) at the Marshall Space Flight Center, the deadline for NRA 8-30 Cycle 1 proposals to solicit research and development ideas in support of 2nd Generation RLVs was November 27, 2000. The deadline for Cycle 2 proposals to provide more focused activities to finalize architecture preliminary design and advanced development of high risk, high priority items was November 15, 2001. The intended outcomes of the Cycle 1 and 2 activities are to meet NASA's highest priority goals for the new 2nd Generation RLV; improving safety such that the probability of crew loss is reduced to less than one in 10,000 flights, and cost to orbit is reduced to less than \$1,000 per pound of payload.

SLI is built on four principles:

1. **Commercial convergence:** NASA seeks to maximize the convergence between commercial, NASA, and where possible Department of Defense (DOD) mission needs, technology requirements and operations

²⁰⁴ http://www.nas.nasa.gov/Groups/Nanotechnology/publications/MGMS_EC1/program/paper.html and <http://venus.hq.nasa.gov/office/budget/fy96/as-1.html> and http://spaceflight.nasa.gov/shuttle/reference/1999_shuttle_ar.pdf

²⁰⁵ <http://www.hq.nasa.gov/office/pao/History/report60.html>

²⁰⁶ <http://www.hq.nasa.gov/office/pao/History/SP-4205/ch9-4.html>

considerations. NASA seeks to fly its unique missions on privately owned and operated launch systems within an integrated architecture.

2. **Competition:** NASA seeks to create an environment of competition to assure the best and most innovative ideas are developed and supported by the SLI. SLI seeks to enable at least two viable commercial competitors in the 2005 timeframe.
3. **Assured access:** NASA seeks to provide access to the International Space Station (ISS) on more than one U.S. launch vehicle. Assured access will be facilitated by developing systems flexibility and standardization as keys to enabling access on more than one launch vehicle.
4. **Evolvability:** NASA seeks to develop systems that can affordably evolve to meet future mission requirements.

The 2nd Generation Reusable Launch Vehicle (RLV) Program Office will implement SLI. The 2nd Gen RLV Program is supported by NASA Field Centers and is led by the Marshall Space Flight Center. NRA 8-30 solicited and implemented the Phase 1 activities selected in Cycle 1 through soliciting involvement with U.S. industry, educational institutions, nonprofit organizations, and U.S. Government agencies (acting as part of a team led by industry or academia) for a broad range of systems engineering and risk reduction research activities. Respondents to NRA 8-30 proposed a variety of research investigations including integrated RLV architectures, systems engineering approaches, architecture trades, business analyses, and required risk reduction activities.

NASA remains committed to obtaining a thorough understanding of the total life cycle of RLV architectures. The Phase 1 architecture definition studies of NRA 8-30 culminate in a detailed System Requirements Review (SRR) by the end of fiscal year 2002. Phase II activities, associated with the decisions made in Cycle 2, will be implemented by separate procurement(s) initiated in mid FY03. NRA 8-30 identifies the timeline for these later Phase II activities, but only solicits and implements the Phase 1 activities.²⁰⁷

²⁰⁷ Complete documentation for the NRA 8-30 RFP is available for review at:
<http://nais.msfc.nasa.gov/cgi-bin/EPSSOL.cgi?acqid=83261#Other>

Whereas the actual RFP is available for review at:
http://nais.msfc.nasa.gov/EPSSOL_DATA/083261-SOL-001-001.doc

And a PowerPoint overview is available for review at:
http://nais.msfc.nasa.gov/EPSSOL_DATA/083261-OTHER-002-001.ppt

5.2 X-PRIZE VEHICLES

5.2.1 Background

In 1927, Charles Lindbergh won the \$25,000 Orteig prize and proved, once and for all, the feasibility of non-stop airplane flights across the Atlantic. A practical and profitable trans-Atlantic airline market that exists to this day developed only a few years after this prize was won. Continuing the prize tradition that encouraged Charles Lindbergh, today the X-Prize encourages the development of privately funded and constructed low-cost, reusable space launch vehicles. Recognizing the effects of inflation since 1927, the X-Prize is set at a value of \$10 Million, and was established May 18, 1996, in St. Louis, MO to encourage the creation of low-cost, passenger-carrying space vehicles.²⁰⁸ The X-Prize rules are simple:

- Only privately funded and constructed vehicles can compete.
- An altitude of 100 km (62 miles) must be attained.
- There must be room on-board for three individuals, although only one individual need be on the first two flights, in which case added weight, equal to the weights of two other people, must be added. (Each is assumed to be 6'2" and 198 lbs.)
- Two flights must be made within two weeks.
- No more than 10% of the flight vehicle's first-flight non-propellant mass may be replaced between the two flights.

The X-Prize Board of Trustees, which includes Erik Lindbergh, grandson of the famed aviation pioneer, created these rules specifically to encourage the development of a mostly reusable, hence cheap, launch vehicle with low operating costs that would be suitable for providing cheap access to space for both private individuals and companies for space tourism and low-cost experimental access to space. By restricting the altitude to 62 miles (100 km), which is above the 50 Miles required for qualifying for Astronaut status as established by NASA, the development of reusable yet risky heat shield and high Mach technology capability is discouraged. Further, by requiring private funding and construction, governments are barred from claiming the prize simply by using any craft already developed to claim the \$10 Million prize.²⁰⁹ A typical X-Prize trajectory is shown in Figure 5-1.

²⁰⁸ The present value of the \$25,000 Orteig Prize as set in 1919 is estimated to be slightly over \$227,000 in 1996 dollars and slightly over \$260,000 in 2002 dollars. See: <http://www.cjr.org/resources/inflater.asp> for one inflation calculator. Examined this way, the X-Prize is actually seen to be a significantly larger prize incentive in relative terms than the Orteig Prize.

²⁰⁹ With the Russians selling tourism access to space for only \$20 Million a seat, a \$10 Million prize would likely attract their attention. For example, their Buran (Snowflake) heavy-lift space shuttle, capable of lifting nearly ten times more weight into orbit than NASA's own shuttle, has reusable hydrogen, oxygen, and kerosene boosters that drop back to an airstrip. The Soviets built two shuttles and three main re-usable boosters, all of which have been mothballed since the early 1990's and which are today under the control

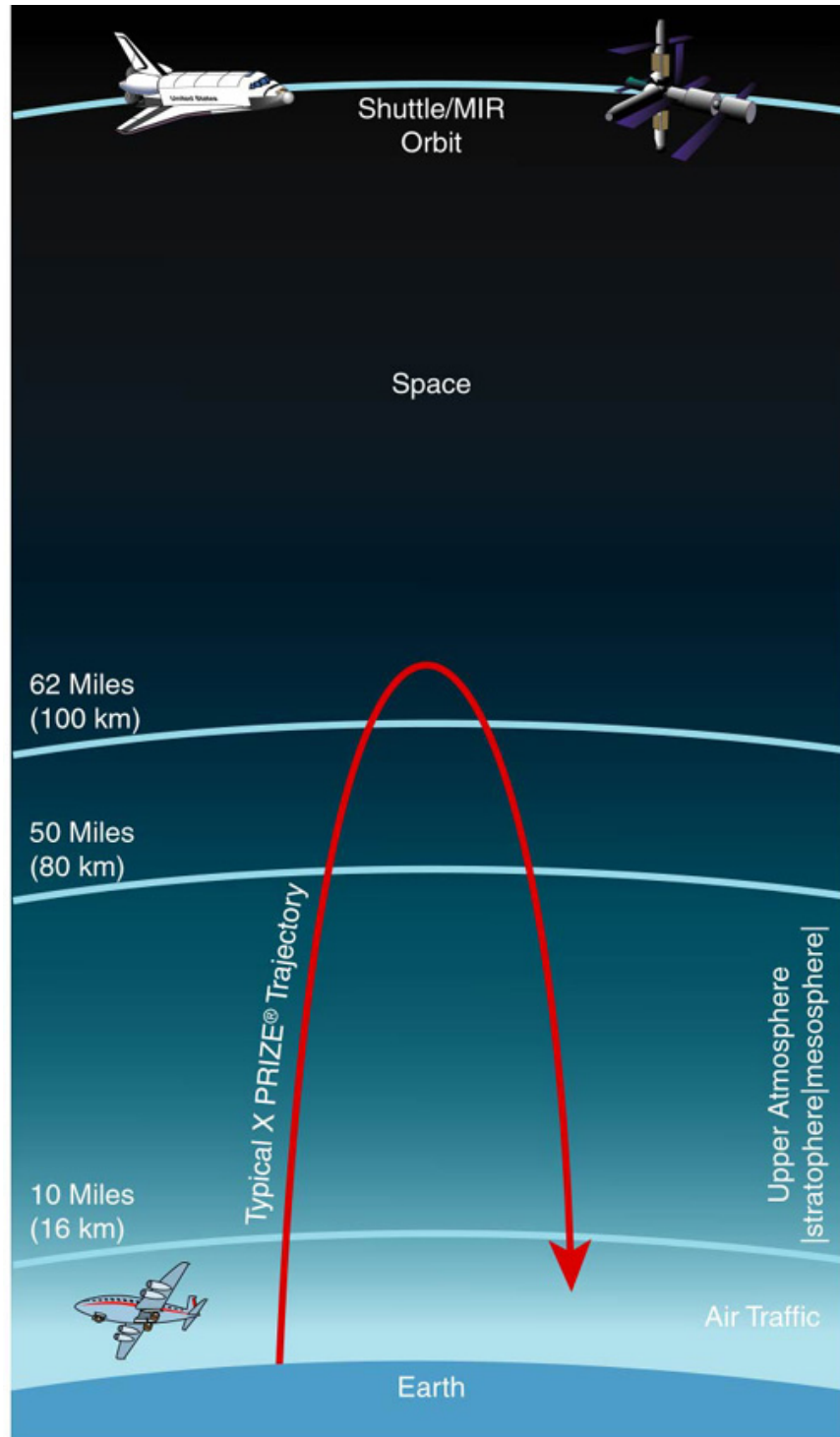


Figure 5-1 X-Prize Trajectory

of the Russians. The Buran system is being updated (2002) and funds from space tourism will likely foot much of the bill for its continued operation. One of the extant Buran shuttles was destroyed during a hanger collapse in May 2002.

See: <http://www.spacedaily.com/news/russia-space-general-01m.html> .

By having three seats, with presumably one for the pilot, the intent of the X-Prize is to stimulate the development of a vehicle that can commence space tourism operation almost immediately after claiming the prize. By having a turnaround time of only two weeks, the amount of “touch-labor” required for flight preparations is likewise reduced. Altogether, these rules encourage the creation of the world’s first affordable space vehicle, intended for sub-orbital flights.

Presently, nineteen entrants from the United States, Russia, Canada, the United Kingdom, and Argentina are registered and competing for the X-Prize. With the downturn in private wealth resulting from the economic conditions that came after Y2K and the subsequent dot-com bust, private project funding has proven especially difficult over the last two years. The team building the ship Pathfinder has even placed requests for funding on their website. Nonetheless, there is a good likelihood that the X-Prize will be won in 2003-2004, i.e., approximately seven or eight years after it was established. (For comparison, the Orteig Prize stood eight years before Lindbergh won it.)

The range of technologies proposed to win the X Prize span from an updated V-2 rocket-motor-powered design resembling Buck Roger’s ship from the 1930’s to a flying-saucer disc. Likewise, planned launches from runways, sea, and even elevated air launch methods achieved either by balloon lift assist or from towing the reusable launch vehicle aloft behind a Boeing 747 are all proposed. One especially optimistic approach plans a single stage and a half to orbit hybrid approach whereby in-flight refueling of rocket propellants is proposed to cut both the weight and cost of expendable first stage boosters. This latter approach bears a close resemblance to the established practice used for fueling SR-71 aircraft, which involves topping-off the fuel tanks only after the aircraft is airborne and the fuel tanks have completely sealed.

Of the many entrants, there are four ships that appear particularly noteworthy and likely to develop into useful sub-orbital vehicles. These four ships are named Thunderbird, PA-X2, Eclipse Astroliner, and MICHELLE-B.

Thunderbird is the ship whose development is being led from the physics department of Salford University (UK) by team leader Steven Bennett. It is a jet-powered vertical takeoff vehicle with turbofan and liquid oxygen and kerosene rockets. The reusable 3-crew capsule is jettisoned from the reusable launch vehicle in flight, and is then flown back to earth suspended from a steerable parasail. Four of the six astronauts for the first two flights have been chosen. The fifth astronaut seat position is (as of March 2002) available for purchase for \$650,000, and the sixth astronaut position is being offered as an international contest prize. Early unmanned test flights have already been conducted to test the various systems, and this craft’s attempt for the X-Prize is planned for 2003. It is likely that the Thunderbird will win the X-Prize in 2003 or early in 2004, barring any major unforeseen problems. As presently configured, this ship will likely not be suitable for much other than very limited space tourism, as the design is optimized for just space tourism, and is not robust enough for use on more than two test flights. The bulk of the reusable launch vehicle market for low-cost access to space for research applications will likely go to another design. Specifically, a design that is more highly reusable and robust

enough to support dozens, if not hundreds, of flights over its useful life, will likely win over Thunderbird in actual tourism and research applications.

The PA-X2 ship is based on updated twenty-year old NASA rocket engine designs, modified to take advantage of modern technology. Dr. Rick Fleeter, President and CEO of AeroAstro, Inc. of Herndon, VA is leading this development. This ship features a rocket-powered liquid oxygen and kerosene rocket engine generating 12,000 lb thrust, and uses a guided, deployable parafoil for recovery. Engine tests have already been conducted, but completion of the crew capsule appears to be several years away. This ship is being developed as the next logical business extension from their present business of building nano-satellites. Although this ship may eventually fly in a manned configuration, it is likely that the X-Prize will already have been won by the time it flies.

Eclipse Astroliner is the ambitious entrant of the project led by Michael Kelly of Kelly Space and Technology of San Bernadino, CA. It is probably the most ambitious of the competing designs, and is based heavily on results of studies done in conjunction with NASA for replacing the present Space Transportation System (Space Shuttle). It features an air-towed launch from a Boeing 747 from any 10,000 ft runway, with the in-flight firing at 20,000 ft of liquid oxygen and kerosene rocket engines. Included in the design is a pivoting nose cone that flips open for launching satellites into orbit when at maximum altitude, before the Eclipse Astroliner itself returns to land on a conventional 10,000 ft runway. Although this design no doubt may become the prime candidate for replacing the present Space Shuttle and Space Transportation System, it is not likely to win the X Prize, for its complexity is so great that complete development will likely not be finished in time to win the \$10 Million X-Prize.

MICHELLE-B is the ship being built by TGV Rockets under the direction of Kent Ewing. This design features pressure-fed kerosene-oxygen engines used for both vertical take-off and vertical landing, with reduced engine power planned during its vertical landing. On the return flight, a drag-shield, shaped like a badminton shuttlecock, is first deployed to reduce the descent speed until within one mile up from the landing site, at which time the engine is re-started at reduced power for the final deceleration and soft vertical landing. This ship is being built specifically to provide low-cost access to space for experiments, and will likely be the second ship to meet the requirements for the X-Prize. Although not the likely winner for the X-Prize, MICHELLE-B will probably become the workhorse that both replaces the present generation of expensive sounding rockets, based on expendable launch vehicles; and which ultimately succeeds at capturing the largest share of the early space tourism market. This is because its no-nonsense robust design should garner the most contracted launches, thereby establishing its safety record first, as required to attract the general space-traveling public.²¹⁰

²¹⁰ History indicates that one should not rule out an underdog from winning. In 1927, the favorite to win the \$25,000 Orteig Prize was Commander Byrd, who only the year before supposedly had been the first to fly over the North Pole. (Modern skeptics are dubious of Byrd's North Pole claim based on a closer review of his supposedly contemporaneous journal that provides evidence that he did not succeed in his claim.) Byrd's attempt at the Orteig Prize cost a well-publicized \$100,000. Lindberg, dubbed "The Flying Fool" in

Ultimately, though, one of the other competing designs for the X-Prize, resembling a conventional airplane or airliner, will undoubtedly capture the bulk of the space tourism business within a decade; analogous to the market success performance of the DC-3 airliner which rolled out on December 17, 1935, only eight years after Lindbergh crossed the Atlantic. It largely replaced the Ford Tri-Motor 5-AT, which had rolled out in the summer of the next year following Lindbergh's flight. Analogous to the Ford Tri-Motor, the MICHELLE-B will likely lose its market share within a decade of when it first flies to a spaceliner having a larger coach compartment and carrying more tourists, thereby reducing the cost per seat to fly into space on sub-orbital flights. Likewise, through having conventional jet engines, and likely being both heavily legislated and ultimately restricted to flying only offshore during both launch and re-entry to eliminate noise pollution over populated areas, such a spaceliner could actually be aloft long enough actually to be able to provide the first-class accoutrements expected by its deep-pocketed paying passengers.²¹¹

The following table contains summary information on all nineteen of the current entrants as of March 2002.²¹²

5.2.2 X-Prize Entrants (March 2002)

1. Ship Name: Advent
 Team Leader: James Akkerman
 Team Description: NASA Retirees
 Propulsion: Oxygen/Natural Gas Rocket
 Citizenship: Houston, Texas, USA
 Launch Site: Water, Vertical
 Landing: Water, Horizontal
 Website: www.ghg.net/jimakkerman/

the press for relying on but a single engine and pilot, actually won. Commander Byrd's "safe" attempt at winning the prize failed at take-off, fogged-in by the same bad weather in which the brash, young 25-year-old Lindbergh felt comfortable flying. To his credit, Commander Byrd was the third to succeed at flying across the Atlantic non-stop, shortly after Lindbergh won the Orteig Prize.

²¹¹ As of March 2002, at least one company is already taking reservations for such flights. Space Adventures, which is the same company that has previously provided access to the orbiting space stations for \$20 Million a trip, and edge-of-space flights aboard a Mig-25 for \$12,595 a trip, is presently taking reservations for sub-orbital flights in 2003-2005 at \$98,000 per flight. For more sub-orbital reservation information, see: <http://www.spaceadventures.com/suborbital/index.html>.

²¹² For more on the X-Prize entrants, <http://www.xprize.org/~Xprize/teams/index.shtml>

2. Ship Name: PA-X2
 Team Leader: Dr. Rick Fleeter
 Team Description: AeroAstro, Inc.
 Propulsion: PA-E LOX / Kerosene Rocket Engine (12,000 lb thrust)
 Citizenship: Herndon, Virginia, USA
 Launch: Rocket Powered Vertical Launch
 Landing: Guided Deployable Parafoil Recovery
 Website: www.aeroastro.com

3. Ship Name: Lucky Seven
 Team Leader: Mickey Badgero
 Team Description: Mickey Badgero & Associates
 Propulsion: Rocket Engines
 Citizenship: USA
 Launch: Rocket Powered Vertical Launch
 Landing: Parasail Landing

4. Ship Name: Ascender
 Team Leader: David Ashford
 Team Description: Bristol Spaceplanes, Ltd.
 Propulsion: Jet and Rocket Engines
 Citizenship: United Kingdom, Bristol, England
 Launch: Conventional Runway
 Landing: Conventional Runway
 Website: www.bristol.spaceplanes.com

5. Ship Name: Canadian Arrow
 Team Leader: Geoffrey Sheerin
 Team Description: Private team.
 Citizenship: Ontario, Canada
 Propulsion: Liquid Fuel 1st Stage Rocket Engine (V-2); 2nd Stage JATO Rockets
 Launch Site: Coastal location
 Landing: Floatation in water
 Website: www.canadianarrow.com

6. Ship Name: Kitten
 Team Leader: James Hill
 Team Description: Cerulean Freight Forwarding Company (telecommuting team)
 Propulsion: Methane & Liquid Oxygen
 Citizenship: Oroville, Washington, USA
 Launch: Conventional Runway
 Landing: Conventional Runway
 Website: www.thriftyspace.com

7. Ship Name: Cosmopolis XXI
Team Leader: Sergey Kostenko
Team Description:
Propulsion: Rocket Engines
Citizenship: Moscow, Russia
Launch Site: Undecided
Landing: Airplane style, or parachute
Website: www.cosmopolis21.ru

8. Ship Name: daVinci
Team Leader: Brian Feeny
Team Description: Canadian Volunteers
Propulsion: Liquid Oxygen/Kerosene System
Citizenship: Canada
Launch Site: Air launch from hot air balloon
Landing: Parachute
Website: www.davinciproject.com

9. Ship Name: The Space Tourist
Team Leader: John Bloomer
Team Description:
Propulsion: Blastwave-Pulsejets
Citizenship: Portland, Oregon, USA
Launch: Conventional Runway
Landing: Conventional Runway

10. Ship Name: The Green Arrow
Team Leader: Dr. Graham Dorrington
Team Description:
Propulsion: Kerosene and Hydrogen Peroxide Rockets
Citizenship: United Kingdom
Launch: Rocket Powered Vertical Takeoff
Landing: Parachute Recovery

11. Ship Name: Aurora
Team Leader: Ray Nielsen
Team Description: Design team in Altamonte Springs, FL
Propulsion: Throttle-able Kerosene & Hydrogen Peroxide Rocket Engine
Citizenship: Orlando, FL, USA
Launch Site: Conventional Runway, subsonic until above 60,000 ft.
Landing: Conventional Runway
Website: www.funtechsystems.com

12. Ship Name: Eclipse Astroliner
 Team Leader: Michael Kelly
 Team Description: Private company + Vought Aircraft; based on early NASA support
 Propulsion: LOX / Kerosene Rocket Engines
 Citizenship: San Bernadino, California, USA
 Launch: Air Towed launch from a 747 from any 10,000 ft. Runway
 Landing: Conventional Runway (10,000 ft.)
 Website: www.kellyspace.com
13. Ship Name: Cosmos Mariner
 Team Leader: Dr. Norman LaFave
 Team Description: Lone Star Space Access Corporation (LSSA), founded in 1995
 Propulsion: Jet and Rocket Engines
 Citizenship: Houston, Texas, USA
 Launch: Conventional Runway
 Landing: Conventional Runway
 Website: www.lonestarspace.com
14. Ship Name: Gauchito (The Little Cowboy)
 Team Leader: Pablo DeLeon
 Team Description: Pablo DeLeon & Associates
 Propulsion: Rocket-Powered
 Citizenship: Buenos Aires, Argentina
 Launch: Vertical
 Landing: Thermal Shield, Parachute
15. Ship Name: XVan2001
 Team Leader: Len Cormier
 Team Description:
 Propulsion: Jet and Rocket Engines
 Citizenship: Washington DC, USA
 Launch: Conventional runway
 Landing: Vertical landing
 Website: www.tour2space.com
16. Ship Name: Pathfinder
 Team Leader: Mitchell Clap
 Team Description: Pioneer Rocketplane, NASA Ames, Scaled Composites (Rutan)
 Propulsion: Turbo-fan, Kerosene/O₂ Rocket, SS ½ TO in-flight propellant re-fueling
 Citizenship: Ann Arbor, MI, USA
 Launch: Conventional Runway
 Landing: Conventional Runway
 Website: www.rocketplane.com (web-pages dated 1999; funding appears desperate.)

17. Ship Name: Thunderbird
 Team Leader: Steven Bennett
 Team Description: Salford University (UK) + Sponsors; 4 of 6 astronauts selected
 2 Seats Open: \$650,000 buys 5th Seat (2nd flight); 6th Seat offered as contest prize
 Propulsion: Turbofan + LOX/Kerosene Rockets
 Citizenship: United Kingdom, Cheshire, England
 Launch: Jet-Powered Vertical Takeoff
 Landing: Steerable parasail 3-crew capsule; parachutes for launch vehicle
 Website: www.starchaser.co.uk
 Launch: 2003
18. Ship Name: MICHELLE-B
 Team Leader: Kent Ewing
 Team Description: TGV Rockets; with strong, no-nonsense management,
 See: www.tgv-rockets.com/Ops_Manual.htm
 Propulsion: Pressure-fed kerosene-oxygen engines
 Citizenship: USA, Bethesda, Maryland
 Launch: Vertical takeoff under primary propulsion
 Landing: Vertical/Soft with drag shield under reduced engine power
 Website: www.tgv-rockets.com
19. Ship Name: Unknown. (Most secretive entrant in the competition.)
 Team Leader: Unknown
 Team Description: Earth Space Transport System Corporation
 Propulsion: Unknown
 Citizenship: Unknown
 Launch: Unknown
 Landing: Unknown
 Website: None

5.2.3 Impact of X-Prize Crafts on Eastern Range & Spaceports

There are two distinctively different phases to be considered in terms of the impacts of X-Prize Crafts on Eastern Range and Spaceport planning. The first phase will consist of the early test flights, whereas the second phase will be the operational flights. Within ten years of becoming operational, it is not likely that the spaceliner type of sub-orbital vehicles resulting from X-Prize activities will require any customary Eastern Range support whatsoever. To attract large numbers of space tourism customers, it would be most convenient simply to base these spaceliners at existing airports with 10,000 ft runways, and add the Spaceport moniker to the Airport name. The spaceliners would take-off and land using the same runways used by airliners. The extant Air Traffic Control system would provide normal tracking of the horizontal flight portion of the flight plans to and from the sub-orbital launch and re-entry areas.

The requirement for minimizing noise over both populated and agricultural animal-husbandry areas would likely put the closest sub-orbital launch and re-entry areas offshore a few hundred miles from existing coastal airports through a requirement for noise reduction over populated areas, as well as through conventionally-powered flight for a significant horizontal flight profile. For enhancing safety, and further to minimize common airspace usage conflicts with slower-flying civilian aircraft, the space launch and re-entry areas would be reserved strictly for sub-orbital crafts and would additionally be clearly marked on air navigation charts.

Likewise, once in-flight during the horizontal flight portion of the excursion, the similarity with existing airliners would likely be maintained. Flight attendants could serve ‘victory’ drinks and snacks while en route back from the designated launch and re-entry areas. (For minimizing space sickness, serving beverages and snacks en route to the launch would probably become prohibited.)

Airport/Spaceport communications, on the other hand, would need to be enhanced to provide high-speed, high-bandwidth communication channels for both on-board entertainments directly beamed to the spaceliner, as well as HDTV in-flight adventure video signals beamed back from the spaceliner to the Spaceport. This adventure video would be popular with Internet-connected family and friends who are following the adventures aboard the spaceliner, as well as being of interest to the merely curious. For ease of use, Web-based forms would likely be popular, allowing Internet-connected observers to select which of several video feeds they would like to watch. This Internet-available video would additionally serve the purpose of providing a sales pitch to interested viewers contemplating a sub-orbital space tourism flight of their own.

To provide the HDTV signals to/from the spaceliner, directional microwave links would be needed to provide these services if directly sent from the Airport/Spaceport, although LEO (Low Earth Orbit) satellites could also provide some of the functions. Ground-based phased arrays could reduce the transmitting power requirements from the Airport/Spaceport, although this would not be a firm requirement. Onboard the spaceliner, on the other hand, thin form-factor planar phased arrays would likely be the only way to provide link-budget margin by providing adequate gain with minimal aerodynamic drag while simultaneously reducing power consumption and the size of hardware equipment avionics modules within the spaceliner.

For initial flights during the first phase of acceptance of X-Prize Crafts, prior to full-scale acceptance of such sub-orbital flights by both governmental agencies as well as by the space-traveling public, Eastern Range support would likely be required on a sporadic, test-basis only, level of support. These requirements would be similar to the present uses of the Range. During the earliest flights, while still unmanned, Destruct-modes would be required. Upon the inclusion of manned crews, the Destruct-modes would likely be dropped. The need for Internet-accessible and selectable on-board video would be minimal, although intensive test telemetry capability would need to be provided. Additionally, it would be during this time that the on-board black-box development upgrades could be done, perhaps providing an emergency data-dump mode for the black

box in the event that a destructive craft break-up occurred during re-entry. Powered by internal primary cells, and perhaps using Ultra Wideband (UWB) modulation techniques, significant data burst throughput consistent with low battery-power consumption would be possible. Once clear of the plasma event of re-entry, it would be useful to have the black-box attempt to burst broadcast its contents prior to sinking into the ocean or impacting the ground. This would expedite the data retrieval in trying to determine after the fact just what went wrong for expendable launch vehicles, especially if the black box were not recovered. The need to encrypt such black box data would be a point of concern, although, in general, it is not likely that any particularly high level of encryption would be required for satisfying operational security concerns. Although *security by obscurity* is not truly safe, it could suffice for a test mode.

5.3 SPACE TUGS

Space Tugs are space vehicles that service other space vehicles or satellites that are (usually) located in higher orbits. Some of the services a Space Tug might provide include:

- Refueling
- Boosting to higher orbit
- Boosting to and from lunar orbit
- Repositioning within similar orbits
- Repair/Replace critical parts
- Return to lower orbit for servicing
- Return to earth via another vehicle
- Surrogate Navigation/Propulsion system
- Removal of space debris by ejecting dead or non-responding satellites out of earth orbit

Theoretically, a Space Tug should be a reusable vehicle; although a label such as “expendable tug” could easily become commonplace. If not reusable, the vehicle is no longer a tug in the “tug boat” concept but a single use expendable rocket with perhaps one of the same missions described above.

One proposed Tug concept is a Geosynchronous Spacecraft Life Extension System (SLES)²¹³. The economic basis behind the SLES is to refuel working communication satellites near the end of their lives; thus avoiding destruction of usable equipment that has simply run low on fuel²¹⁴.

²¹³ <http://www.spaceref.com/news/viewpr.html?pid=9170>

²¹⁴ <http://uk.news.yahoo.com/020903/12/d8r07.html>

5.3.1 Background

Lockheed proposed a manned, multi-arm, Space Tug in 1963.²¹⁵ NASA proposed two different space tugs in the 1980's. Plans were usually based on the aerobraking concept. A NASA/Marshall concept from 1985 was equipped with a large disc-shaped aeroshell that slowed the vehicle down as it passed through the Earth's upper atmosphere (Figure 5-2). The space tug could then return heavy payloads from geostationary or lunar orbit without using any fuel to rendezvous with the low Earth orbit space station²¹⁶. The second vehicle was a lifting body that was also based on aerobraking (Figure 5-3)²¹⁷

General Dynamics proposed a modular design in 1984. Modular spherical LOX & LH2 tanks would be added as needed for the mission.



Figure 5-2 NASA 1985 Space Tug Concept #1

²¹⁵ <http://www.astronautix.com/craft/locsetug.htm>.

²¹⁶ <http://www.astronautix.com/craft/spacetug.htm>

²¹⁷ <http://www.abo.fi/~mlindroo/Station/Slides/sld007.htm>

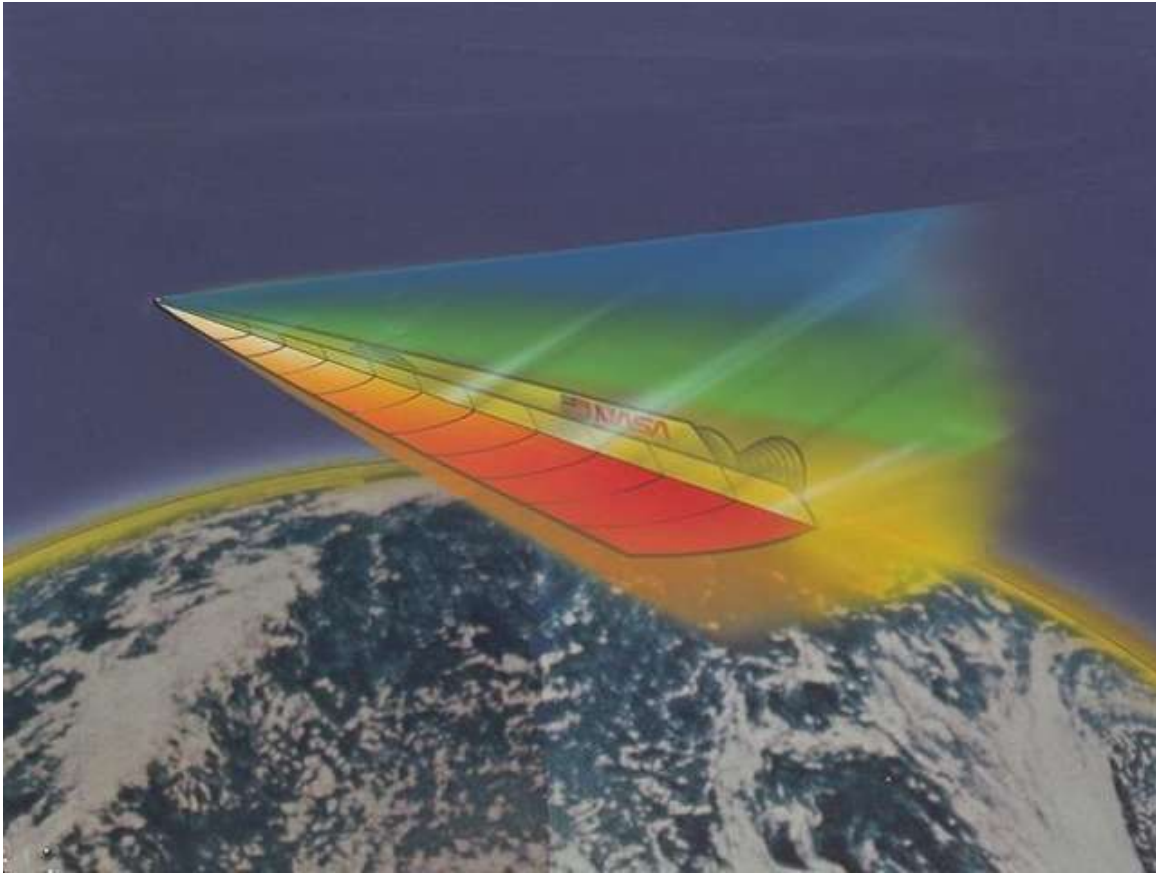


Figure 5-3 NASA 1985 Space Tug Concept #2

Russia presented a large space tug concept in 1998 at Berlin Exhibit²¹⁸.

5.3.2 Impact of Space Tugs on Range Architecture

The Space Tugs should have little impact on Spaceport or Range designs since they will likely spend most of their life in orbit. Processing for launch through a Spaceport or Range would likely be handled as cargo.

²¹⁸ <http://studweb.studserv.uni-stuttgart.de/studweb/users/lrt/lrt28256/vehicles/salytug.htm>

5.4 TAV (BLACK HORSE)

5.4.1 Background

Military planners predict that by 2020, a U.S. Aerospace Force will be a reality. Based on squadrons of rocket-powered TransAtmospheric Vehicles (TAVs), also referred to as Black Horse vehicles, the individual vehicles of the U.S. Aerospace Force are expected to be about the size of an F-16 fighter. Each of these vehicles will be capable of placing an approximately 5,000 pound payload into low earth orbit (LEO), or of delivering slightly larger payloads on sub-orbital trajectories, from and to anywhere in the world.

Additionally, these vehicles will be designed to support fast response needs, and to launch LEO or sub-orbital sorties within one hour of completion of mission planning. Aerospace superiority is the ultimate goal for the Black Horse vehicles when in orbit. When operating in support of an area conflict, an aerospace wing will have the capability to put mission specific payloads either on-orbit (i.e., mission-tailored satellites) or on-target (i.e., precision guided munitions) literally anywhere in the world within just a few hours after identification of a need.²¹⁹

The overarching difficulty in meeting Black Horse vehicle capability is the choice of a space propellant suitable for in-flight refueling that also provides start and re-start capabilities during highly variable mission sorties. Current generation NASA and commercial launch vehicles use only four types of propellants:

- Petroleum-based rocket fuel is a type of highly refined kerosene called RP-1 (Refined Petroleum-1) that is, at present, burned with liquid oxygen (the oxidizer) to provide thrust.
- Cryogenic propellants are liquid oxygen (LOX), which serves as an oxidizer, and liquid hydrogen (LH₂), which is the fuel. To guarantee production of thrust, the LOX and LH₂ require an ignition source. The distressing tendency of cryogenics to return to gaseous form unless kept super-cold makes it difficult to store LOX and LH₂ over long periods of time, or to accomplish in-flight refueling safely.
- Hypergolic propellants (i.e., hypergols) are fuels and oxidizers that ignite on contact with each other and which require no ignition source. This easy start and restart capability makes them especially attractive for spacecraft maneuvering systems used during docking and orbit-modifying maneuvers. Another plus is their storability — they do not have the extreme temperature requirements of cryogenics, and are more easily stored for long periods of time. The fuel is monomethyl hydrazine (MMH) and the oxidizer is nitrogen tetroxide (N₂O₄). Their toxicity is extreme to say the least, and leakage of either fuel or oxidizer during in-flight refueling would at the least be extremely toxic, and potentially disastrous, in terms of both vehicle and crew safety.

²¹⁹ <http://www.airpower.maxwell.af.mil/airchronicles/apj/spacast3.html>

- Solid-propellant rocket motors are the oldest and simplest of all rockets, dating back to the ancient Chinese. In their simplest form, these consist of a casing filled with a mixture of solid-form chemicals (fuel and oxidizer) that burn at a rapid rate, expelling hot gases from a nozzle to achieve thrust. The disadvantage is that once started, they usually cannot be extinguished, and cannot easily provide the start and re-start capability necessary for orbital maneuvering and attitude station keeping. Neither can they easily be refueled while in-flight.

In place of any of these existing propellants, a new type of propellant is planned for Black Horse. To minimize complexity, reduce operating cost, and improve response time, the Black Horse vehicles will likely use a petroleum-based standard jet fuel and a non-cryogenic oxidizer in the form of hydrogen peroxide (H₂O₂). This fuel was selected by a U.S. Air Force study conducted in 1993-1994 by the U.S. Air Force's Phillips Laboratory in association with WJ Schafer Associates and Conceptual Research Corporation. With this choice of fuel and oxidizer, the myriad propellant drawbacks of cryogenics, hypergolics, and solids are all avoided, thereby simultaneously eliminating the numerous difficulties of toxicity, limited storage life, spontaneous combustion, and in-flight refueling. With this Aerial Propellant Transfer (APT) technology, the reuse of existing tanker and in-flight refueling technology is likewise maximized, and development costs are minimized.

In addition to the choice of fuel and oxidizer, the 1993-1994 study also investigated the two in-flight refueling methods currently used for U.S. military jet aircraft and for Air Force One: the Navy's probe and drogue system and the Air Force's boom refueling system. The probe and drogue system eliminates the need for detailed in-flight, second-by-second cooperation between the tanker aircraft crew and the receiving craft pilot during refueling operations, but it can only provide fuel transfer rates up to 250 gallons per minute. For the boom system, a higher transfer rate of 1,200 gallons per minute is possible, but requires second-by-second cooperation between the boom operator and the receiving craft pilot. Because of its higher rate of fuel transfer, the boom approach was recommended for the Black Horse refueling method over the probe and drogue system. Both the KC-10 and KC-135 tankers support boom system refueling. However, the KC-135Q and KC-135T additionally provide an isolated fuel system from which the aircraft does not draw its own jet fuel. These two aircraft would therefore permit the storage of the new proposed Black Horse jet fuel and hydrogen peroxide mixture in the refueling tank(s) while retaining the standard jet fuel and engines of existing KC-135Q and KC-135T tankers. Using either of these two specific tankers, no re-design of existing tanker technology will be needed to support Black Horse in-flight refueling.²²⁰

Maintenance and ground operations for the Black Horse will require no greater specialized skills than those for other aircraft. TAVs returning from a mission will

²²⁰ <http://www.rocketplane.com/History.html>

normally be serviced and returned to ready-for-flight status in less than a day and can be surged to fly multiple sorties per day, if necessary. If tankers were pre-positioned in-theater, TAVs could also fly high-priority, global, cargo-delivery missions.

To fully exploit the Black Horse's capabilities, designers need to adopt a new approach to satellite design --- one that maximizes miniaturization and modularity. Most space systems' designers will take advantage of the vastly lower cost per pound to orbit (less than \$1,000 per pound) that the Black Horse concept provides. Orbital payloads too large to fit in a single TAV can be designed in modular form, launched in pieces, and assembled on-orbit. High-value satellites can be serviced, repaired, and modernized in space by utilizing space tugs. Space tugs will move payloads launched on the TAVs to the mission orbit. With space launch and operations made routine by the Black Horse, multiple new uses for space systems will emerge, and the design cycle for new systems will be greatly reduced. Such systems will be less expensive, simpler, and quicker to make. They will likewise allow more rapid inclusion of emerging commercial technologies.

The strategy advocated with TAV's, considering their reduced payload size and low operating costs, rests on the following three assumptions:

- The technology that drives space payloads (sensors, electronics, software, etc.) is advancing rapidly, even accelerating. This makes large, complex satellites (because of their lengthy cycles of design and construction) more vulnerable to obsolescence on orbit and favors an approach that regularly places more up-to-date systems on-orbit.
- These same technological advances will increasingly allow more capability to be packaged into smaller volumes. Modularity, interferometry, bi-static radar techniques, and other technologies may allow functions traditionally believed to require large, monolithic platforms to be put in space incrementally and subsequently either assembled on-orbit or operated as a distributed system.
- Economies of scale have proven elusive for the first forty years of launching space systems. Large boosters are not appreciably (an order of magnitude) more cost effective (measured in dollars per pound on orbit) than small boosters, and no projected demand or incremental improvements will significantly (again, by an order of magnitude, or more) reduce the cost of current boosters.

5.4.2 Impact of TAVs on Range Architecture

TAV's may be a major driving force in developing a future Military Ranges (see Section 6). Their classified missions, mission planning, ordnances, ground fueling, aerial refueling, maintenance, logistics, basing, training, vehicle turn-around and mission debriefing can best be accommodated within the closed security and infrastructure of an RLV-Military future range, i.e., a future U.S. Aerospace base.

5.5 ADDITIONAL LAUNCH CONCEPTS

There are many ways to categorize launch vehicles. Historically, the following classifications have been used:

- Reusable / Expendable
- Orbital / Sub-orbital
- Air Breathing / LOX Powered

Another way to categorize launch concepts is with respect to their takeoff and landing characteristics. Table 5-1 presents a matrix that summarizes the majority of all launch concepts.

Table 5-1 Launch Concepts

Landing / Takeoff	Vertical TO	Horizontal TO
Vertical Landing	VTVL	HTVL
Horizontal Landing	VTHL	HTHL

In addition, there are some concepts where the vehicle does not fit into any conventional rocket category. These concepts, such as Railgun, Space Cannon and Space Elevator are discussed later in this section.

5.5.1 Vertical Takeoff – Vertical Landing (VTVL)

Vertical Takeoff – Vertical Landing is one of the more flexible concepts. Examples can be simple and very energy efficient while others are complex and require large energy sources.

Some of the vehicles that use this concept are as follows:

- Mercury/Gemini/Apollo
- Lunar Lander
- Delta Clipper
- K-1
- TGV
- Roton

Mercury/Gemini/Apollo – America first family of space vehicles were vertical takeoff and vertical landing. Various rockets were used to launch the one-place Mercury (Figure 5-4), two-place Gemini (Figure 5-5) and three-man Apollo (Figure 5-6) capsules. Landings were parachute-assisted splashdowns.



Figure 5-4 Mercury Capsule



Figure 5-5 Gemini Capsule



Figure 5-6 Apollo Capsule

Lunar Lander - The Lunar Lander (Figure 5-7) was a vertical takeoff - vertical landing vehicle. Its mission required that these be executed in reverse of the usual order.

Descent to the moon was vertical using rocket thrust to counteract moon's gravity. Takeoff from the moon was vertical using rocket thrust to escape the lunar surface and to return to the command module.



Figure 5-7 Lunar Lander

Delta Clipper – The Delta Clipper (Figure 5-8) was a single stage to orbit, fully reusable launch vehicle designed by McDonnell Douglas²²¹. The concept used a rocket powered vertical takeoff with a rocket powered vertical landing. Various test flights were successfully flown before the prototype exploded in 1996. The 43-foot vehicle was destroyed during a post-landing tip-over and fire while being tested at White Sands Missile Range, NM. The primary cause of the vehicle mishap was that the brake line on the helium pneumatic system for landing gear #2 was not connected. The vehicle became unstable upon landing, toppled onto its side, exploded, and burned.²²²



Figure 5-8 McDonnell Douglas Delta Clipper

K-1 – The Kistler Aerospace K-1 is a fully reusable vehicle designed to return its two stages to earth to be reused repeatedly. It uses a rocket powered vertical takeoff. At an altitude of 135,000 feet, 121 seconds after liftoff, the first and second stages separate. After separation, the second stage, or "orbital vehicle," ignites a single NK-43 rocket engine and proceeds to low earth orbit with its payload²²³. The first stage returns to earth using a parachute system (Figure 5-9). Parachutes are deployed at 10,000 feet and airbags are deployed just prior to a soft touchdown. The stage is then prepared for another flight.

²²¹ <http://gargravarr.cc.utexas.edu/ssrt/>

²²² <http://gargravarr.cc.utexas.edu/ssrt/news/97-q1/970108-dcxa-report.txt>

²²³ http://www.kistleraerospace.com/k1_flight_profile/flight2.html

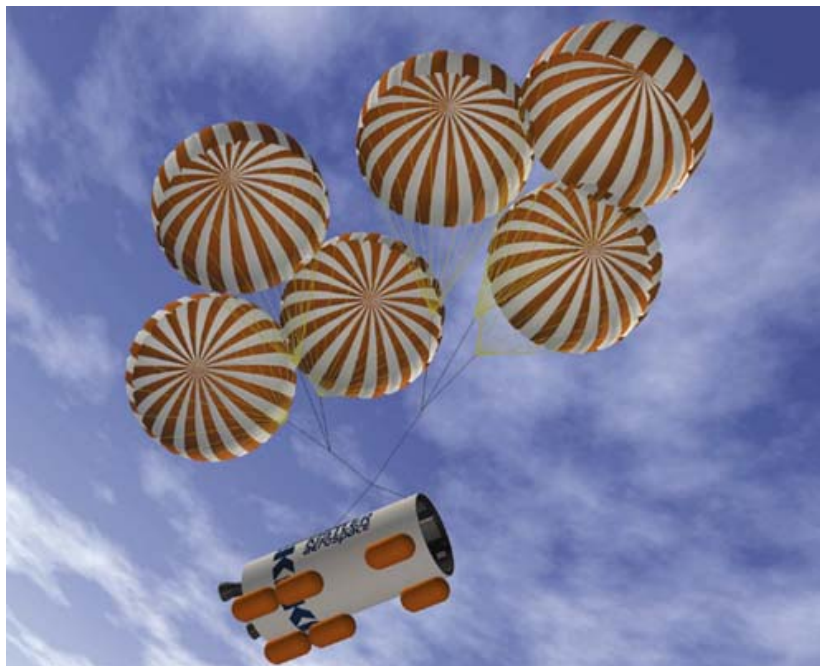


Figure 5-9 First Stage Recovery of K-1 (concept)

After achieving orbit, the payload is deployed and the orbital vehicle does a pitch over maneuver and fires the maneuvering engines to de-orbit. It re-enters the earth's atmosphere nose first on a controlled trajectory to the launch site. At 10,000 feet, parachutes are deployed to brake the descent velocity. Airbags are deployed just prior to touchdown for a soft landing at the launch site (Figure 5-10). The vehicle is then prepared for the next flight, within days after landing.



Figure 5-10 Second Stage Recovery of K-1 (concept)

TGV – TGV has proposed an X-Prize entry (Figure 5-11) that uses rocket powered vertical takeoff and landing. The concept also uses aero-braking.



Figure 5-11 TGV X-Prize Entrant (concept)

Roton - The Roton (Figure 5-12) is a reusable, single-stage-to-orbit (SSTO) space vehicle designed to transport up to 7000 lbs to and from low earth orbit. The Roton is conical in shape, 22 feet (6.7 meters) in diameter at the base, and about 63 feet (19.2 meters) tall. The rounded base of the Roton contains the vehicle's main propulsion system, and the engines fire through apertures in the base. During reentry from orbit the base doubles as the vehicle's heat shield. The Roton deploys a rotor system to provide a controlled gliding approach to the landing site. Scaled Composites is currently building the ATV (atmospheric test vehicle). This is a full size prototype to test the rotor recovery system²²⁴.

²²⁴ <http://www.scaled.com/>



Figure 5-12 Roton X-Prize Entrant (concept)

5.5.2 Vertical Takeoff – Horizontal Landing (VTHL)

The Vertical Takeoff – Horizontal Landing is a familiar concept, having been selected for the first reusable space vehicle, the Space Shuttle. This is an efficient concept because it allows use of nearly all of the fuel during the ascent stage of the mission. The vehicle then returns for a glider type landing, with little or no fuel left onboard.

Some of the vehicles that use this concept are:

- Space Shuttle
- SLI (Shuttle 2nd Gen)
- X-33
- X-37
- X-38

Space Shuttle – The Space Shuttle is the world’s first reusable space vehicle. In the launch configuration, the orbiter and two SRBs are attached to the external tank in a vertical (nose-up) position on the launch pad. Each SRB is attached at its aft skirt to the mobile launcher platform by four bolts. At launch, the three Space Shuttle main engines – fed liquid hydrogen fuel and liquid oxygen oxidizer from the external tank – are ignited first. When it has been verified that the engines are operating at the proper thrust level, a signal is sent to ignite the SRBs. At the proper thrust-to-weight ratio, initiators (small explosives) at eight hold-down bolts on the SRB are fired to release the Space Shuttle for liftoff. All this takes only a few seconds (Figure 5-13).



Figure 5-13 Space Shuttle Launch

Approximately 1 minute later (2 minutes into the ascent phase), the two SRBs have consumed their propellant and are jettisoned from the external tank. The boosters briefly continue to ascend, while small motors fire to carry them away from the Space Shuttle. The boosters then turn and descend, and at a predetermined altitude, parachutes are deployed to decelerate them for a safe splashdown in the ocean. Splashdown occurs approximately 141 nautical miles (162 statute miles) from the launch site. The boosters are recovered and reused.

Meanwhile, the orbiter and external tank continue to ascend, using the thrust of the three Space Shuttle main engines. Approximately 8 minutes after launch and just short of orbital velocity, the three Space Shuttle engines are shut down (main engine cutoff), and the external tank is jettisoned on command from the orbiter (Figure 5-14).



Figure 5-14 Separation of External Tank (concept)

The external tank continues on a ballistic trajectory and enters the atmosphere, where it disintegrates. Its projected impact is in the Indian Ocean.

The orbital altitude of a mission varies depending upon that particular mission. The nominal altitude can vary between 100 to 217 nautical miles (115 to 250 statute miles). The forward and aft Reaction Control System (RCS) thrusters (engines) provide attitude control of the orbiter as well as any minor translation maneuvers along a given axis on orbit.

At the completion of orbital operations, the orbiter is oriented in a tail-first attitude by the reaction control system. The two Orbital Maneuvering System (OMS) engines slow the orbiter for deorbit. The reaction control system then turns the orbiter's nose forward for entry. The reaction control system controls the orbiter until atmospheric density is sufficient for the pitch and roll aerodynamic control surfaces to become effective.

Entry interface is considered to occur at 400,000 feet altitude approximately 4,400 nautical miles (5,063 statute miles) from the landing site and at approximately 25,000 feet per second velocity. At 400,000 feet altitude, the orbiter is maneuvered to zero degrees roll and yaw (wings level) and at a predetermined (40 degrees) angle of attack for entry.

The forward RCS engines are inhibited prior to entry interface, and the aft reaction control system engines maneuver the spacecraft until a dynamic pressure of 10 pounds per square foot is sensed, which is when the orbiter's ailerons become effective. The aft RCS roll engines are then deactivated. At a dynamic pressure of 20 pounds per square foot, the orbiter's elevators become active, and the aft RCS pitch engines are deactivated. The orbiter's speed brake is used below Mach 10 to induce a more positive downward elevator trim deflection. At approximately Mach 3.5, the rudder becomes activated, and the aft reaction control system yaw engines are deactivated at 45,000 feet.

Entry guidance must dissipate the tremendous amount of energy the orbiter possesses when it enters the Earth's atmosphere to assure that the orbiter does not either burn up (entry angle too steep) or skip out of the atmosphere (entry angle too shallow) and that the orbiter is properly positioned to reach the desired touchdown point.

During entry, energy is dissipated by the atmospheric drag on the orbiter's surface. Higher atmospheric drag levels enable faster energy dissipation with a steeper trajectory. If the orbiter is low on energy (current range-to-go much greater than nominal at current velocity), entry guidance will command lower than nominal drag levels. If the orbiter has too much energy (current range-to-go much less than nominal at the current velocity), entry guidance will command higher-than-nominal drag levels to dissipate the extra energy.

Excess energy is dissipated with an S-turn; and the speed brake can be used to modify drag, lift-to-drag ratio and flight path angle in high-energy conditions. This increases the

ground track range as the orbiter turns away from the nearest Heading Alignment Circle (HAC) until sufficient energy is dissipated to allow a normal approach and landing guidance phase capture, which begins at 10,000 feet altitude. The spacecraft slows to subsonic velocity at approximately 49,000 feet altitude, about 22 nautical miles (25.3 statute miles) from the landing site.

The approach and landing phase begins at about 10,000 feet altitude at an equivalent airspeed of 290, plus or minus 12, knots 6.9 nautical miles (7.9 statute miles) from touchdown. Autoland guidance is initiated at this point to guide the orbiter to the minus 19- to 17-degree glide slope (which is over seven times that of a commercial airliner's approach) aimed at a target 0.86 nautical mile (1 statute mile) in front of the runway. The spacecraft's speed brake is positioned to hold the proper velocity. The descent rate during approach and landing is greater than 10,000 feet per minute (a rate of descent approximately 20 times higher than a commercial airliner's standard 3-degree instrument approach angle).

At 1,750 feet above ground level, a pre-flare maneuver is started to position the spacecraft for a 1.5-degree glide slope in preparation for landing with the speed brake positioned as required. The flight crew deploys the landing gear at this point and touchdown occurs shortly thereafter²²⁵.

SLI – The Space Launch Initiative is investigating technologies for the second generation of Space Shuttle. Many, but not all, concepts have chosen a VTHL (vertical takeoff – horizontal landing) configuration using multiple stages²²⁶. Each stage would have the capability to return to the launch site for refurbishment and reuse. Many concepts have the returning Stage 1 and Stage 2 vehicles as unmanned drones. One such concept is shown in Figure 5-15.

X-33 – The X-33 (Figure 5-16) or VentureStar was an unmanned vehicle that would have taken off vertically like a rocket and which would have landed horizontally like an airplane. This Lockheed-Martin designed test vehicle was to have reached an altitude of 50 miles and high hypersonic speeds. The X-33 program was managed by the Marshall Space Flight Center and was to have been launched at a special launch site on Edwards Air Force Base. One of its unique features was its Linear Aerospike engine²²⁷. Due to technical problems with the liquid hydrogen fuel tank, and the resulting schedule delay and cost increase, the X-33 program that began in 1996 was cancelled in February 2001²²⁸.

²²⁵ <http://spaceflight.nasa.gov/shuttle/reference/shutref/sts/profile.html>

²²⁶ <http://www.slinews.com/concepts.html>

²²⁷ <http://members.lycos.co.uk/spaceprojects/x-33.html>

²²⁸ <http://trc.dfrc.nasa.gov/gallery/photo/X-33/HTML/EC95-43320-1.html>



Figure 5-15 NASA SLI General Concept



Dryden Flight Research Center EC96-43631-9 Artist Conception 1996
X-33



Figure 5-16 X-33 Concept

X37 – NASA’s X-37 (Figure 5-17) is an advanced technology flight demonstrator. It is an unmanned, reusable launch vehicle, and is designed to operate in both the orbital and reentry phases of flight.



Figure 5-17 X-37 in Shuttle Cargo Bay (concept)

The X-37 is capable of being ferried into orbit by the Space Shuttle or an expendable launch vehicle. It is designed to operate at speeds up to 25 times the speed of sound and to test technologies in the harsh environments of space and atmospheric reentry.

The X-37 program began in 1998. Its purpose is to demonstrate dozens of advanced airframe, avionics and operations technologies that can support various launch vehicle and spacecraft designs. A major focus of the X-37 will seek improvement of today’s spacecraft thermal protection systems.

The Boeing-designed X-37 is 27.5 feet long — about half the length of the Shuttle payload bay — and weighs about 6 tons. Its wingspan is about 15 feet, and it contains an experiment bay 7 feet long and 4 feet in diameter.

The X-37’s on-orbit propulsion is provided by the AR-2/3, a high reliability engine with a legacy stretching back to the 1950s. Hydrogen peroxide and JP-8 will propel the X-37 engine.

The X-37’s shape is a 120 percent scale derivative of the Air Force’s X-40A (Figure 5-18), also designed and built by Boeing, which was released from a helicopter and glide-tested in 1998.²²⁹

²²⁹ <http://www1.msfc.nasa.gov/NEWSROOM/background/facts/x37.html>



Figure 5-18 X-40

X-38 – The X-38 (Figure 5-19) was designed as a crew rescue vehicle (CRV) for the International Space Station. It would be carried aloft in the space Shuttle cargo bay (vertical takeoff) and would land using a lifting body and steerable parafoil.²³⁰ When operational, the CRV would be an emergency vehicle to return up to seven International Space Station (ISS) crewmembers to Earth. If an emergency arose that forced the ISS crew to leave the space station, the CRV would be undocked, perform a deorbit burn, and return to Earth much like a space shuttle. The vehicle's life support system would have a duration of about seven hours. A steerable parafoil parachute would be deployed at an altitude of about 40,000 feet to carry it through the final descent and the landing.²³¹ Two airframes were manufactured and a total of 15 flights were flown between 1997-2001.



Figure 5-19 X-38

²³⁰ <http://www.dfrc.nasa.gov/History/x-planes.html>

²³¹ <http://www.dfrc.nasa.gov/PAO/PAIS/HTML/FS-038-DFRC.html>

5.5.3 Horizontal Takeoff – Vertical Landing (HTVL)

Horizontal Takeoff – Vertical Landing has, to date, not been a popular configuration. Some air launched expendable vehicles do fall under this concept

The vehicle closest to using this concept is as follows:

- Pegasus

Pegasus – The Pegasus (Figure 5-20) is not a true Horizontal Takeoff – Vertical Landing concept since it usually is full expendable and has no landing component. In theory, a payload could be ejected and parachuted back to earth; thus allowing it to fit this concept. Orbital Sciences Corporation, (OSC), developed the Pegasus launch vehicle. The Pegasus launch vehicle consists of three solid rocket motor stages with a wing and fins for lift and attitude control of the first stage and gimbaled rocket nozzles on the second and third stages. The vehicle is carried aloft horizontally by an L-1011 aircraft. It is dropped from the carrier aircraft at approximately 40,000 ft and .8 Mach. Upon motor ignition, the vehicle accelerates to a velocity of 8,300 fps (8.3 Mach) and performs a 2.5 g positive pull up to the correct trajectory angle. The 2nd and 3rd stages are then fired sequentially to place the payload into orbit²³².



Figure 5-20 Orbital Sciences' Pegasus

²³² <http://www.scaled.com/>

5.5.4 Horizontal Takeoff – Horizontal Landing (HTHL)

The Horizontal Takeoff – Horizontal Landing can be an energy efficient concept. Various future air launch designs will use this concept. An aircraft will take off horizontally and climbs to altitude where it releases the space vehicle that continues into orbit (or sub-orbit). Both the aircraft and vehicle will then land vertically.

Some of the vehicles that use this concept are as follows:

- TAV (TransAtmospheric Vehicles)
- SLI (Shuttle 2nd Gen)
- X-30
- X-34
- Eclipse

TAV – The TAV or Black Horse is a proposed military space plane about the size of an F-18. It would take off horizontally and climb out to a waiting tanker. The tanker would refuel the TAV with fuel (JP-5) and oxidizer (H₂O₂). The vehicle would then proceed with its suborbital or orbital mission. Upon completion of the mission, the vehicle would return to earth and land horizontally.²³³

SLI – At least one concept for the Space Launch Initiative's Second Generation Shuttle uses a HTHL (horizontal takeoff – horizontal landing) approach. Northrop Grumman/Orbital Sciences Corporation investigated many concepts. One of their concepts involves a spaceplane riding aloft piggyback on a large flying wing with multiple jet engines²³⁴. Upon reaching altitude, the two vehicles separate, and the spaceplane continues to space with its payload. The flying wing returns to base under its own power.^{235 236}

X-30 – The X-30 program was to develop a horizontal takeoff and landing, single stage to orbit, space plane. It was sometimes referred to as the Orient Express. A 1/3-scale concept demonstrator (Figure 5-21) was built, and "flown" only in a high-temperature tunnel between 1986-1994. This joint effort by NASA, the Department of Defense, and five major contractors explored development of technologies for a new generation of aerospace vehicles for hypersonic cruise in the atmosphere or single-stage-to-orbit using air breathing primary propulsion and horizontal takeoff and landing. The program had expected to produce a vehicle that could fly at Mach 25. The program developed

²³³ <http://www.airpower.maxwell.af.mil/airchronicles/apj/spacast3.html>

²³⁴ <http://www.slinews.com/concepts.html>

²³⁵ <http://www.slinews.com/videoarchitecture.html>

²³⁶ <http://www.slinews.com/video/grumman.mov>

significant advances in high-temperature, carbon-carbon materials, lightweight titanium and beryllium alloys, and high strength, corrosion-resistant titanium-alloy composites.²³⁷



Figure 5-21 X-30 (concept)

²³⁷ <http://www.dfrc.nasa.gov/History/x-planes.html>

X-34 – The X-34 (Figure 5-22) was a reusable, unmanned suborbital spacecraft designed by Orbital Sciences Corporation. The vehicle was to be launched from a Lockheed L-1011 airplane. After its mission, it would land horizontally like an airplane. The X-34 had a 27-foot wingspan and was 58-feet long²³⁸. It is designed to reach speeds up to Mach 8 at altitudes of up to 50 miles. The craft was designed to have a small ground and support crew of about 12 people to service it and provide a two-week turnaround time between flights. The program began in 1996 and was cancelled in February 2001²³⁹.



Figure 5-22 X-34 (concept)

²³⁸ http://www.space.com/missionlaunches/launches/x34_825.html

²³⁹ http://www.space.com/business/technology/business/x34_update.html

Eclipse – The Eclipse (Figure 5-23) is an X-prize contestant that uses a unique tow arrangement for takeoff. Eclipse will first be towed, like a glider, behind a large jumbo jet. All fuel and cargo will be onboard. Once an altitude of 20,000 ft is reached, the Eclipse will detach from the jet and fire its engines to reach sub-orbital altitudes where it can release its payload. It uses a horizontal landing concept that will enable it to operate from any commercial airport.²⁴⁰



Figure 5-23 Eclipse Being Towed For Takeoff By Large Commercial Jet (concept)

²⁴⁰ <http://www.geocities.com/spacetransport/xprize-htol2sto.html>

5.5.5 Railgun

Railguns have been proposed by some as an inexpensive, cost effective method of placing space vehicles into orbit. Unlike magnetic levitation launch systems (see Figure 5-24) that merely accelerate launch vehicles to a relatively low speed to reduce the volume of on-board fuel that must be carried during launch, railguns are instead intended to be used to accelerate launched items without engines to extremely high velocities near the ground. Railguns also require a current-carrying conductor to be embedded in the launch vehicle, unlike magnetic levitation launch systems, and additionally require the launch vehicle to maintain contact with the rail during acceleration to permit current flow to occur.

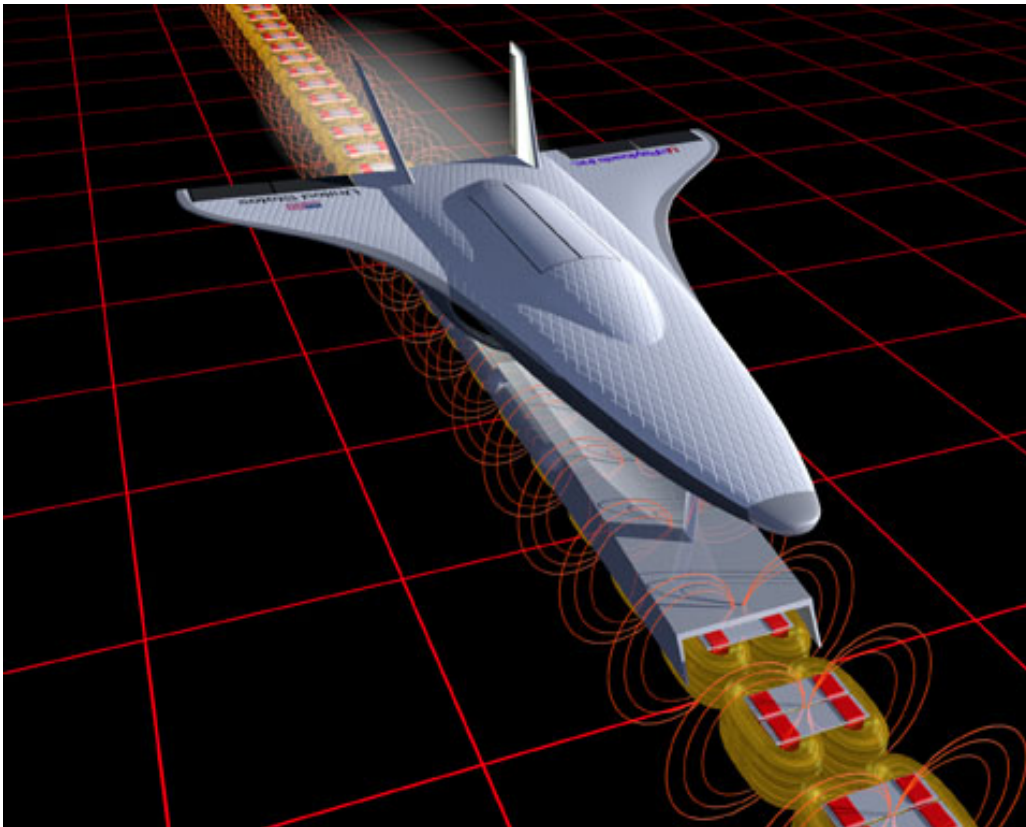


Figure 5-24 Magnetic Levitation Launch (concept)

Before discussing the applicability of Railgun launch platforms to Spaceports, an overview of the key characteristics of railguns is warranted. As discussed in this section, railguns:

- Use electromagnetically energized rails to launch payloads in place of chemically powered rockets
- Can provide quick launch-responsiveness for small payloads
- Are environmentally friendly
- Can achieve low launch costs

- May expose payloads to accelerations in excess of 1,000 Gs for practical-sized railguns. Such loads would limit their use to especially designed small, inorganic payloads
- Generate loud sonic booms (reports) at launch, limiting railgun launchers to use only at remote Spaceports where noise is not an issue
- Require dc launch currents in the hundreds of millions of amps at extremely high voltages
- Benefit from having their rails operated in a vacuum

Because of their theoretical advantages, railguns are often considered for launching nano-satellite payloads from future Spaceports. For this reason, their likely influence on Advanced Range requirements within the next several decades should be addressed. However, because of their present disadvantages, barring any major breakthroughs in either creating high-temperature super-conducting materials to fabricate the rails or launched item current-carrying conductor, or in easing high-current, high-voltage dc power generation; it is not likely that widespread, general use of railgun launchers will occur at Spaceports over the next three decades. In support of these claims, the following investigation explores railgun technology in considerably more detail.

Instead of forces derived from explosive propellant charges or rocket engines, a railgun uses electromagnetic forces to accelerate objects to high velocities. Relative to conventional terrestrial launch techniques, railguns entirely avoid any reduction of sub-orbital payload mass due to carrying onboard fuel and engines. Theoretically, railguns also provide quick responsiveness for launching items, have minimal environmental impacts in comparison with solid or chemical rocket boosters, and should achieve an excellent operating cost in terms of pounds of payload launched. On the other hand, because of a lack of fuel and engines, each item launched by a railgun is also at its highest velocity at the instant it leaves the railgun, which is where the payload is at its lowest possible altitude in its entire trajectory, and where air resistance is at its maximum. Payloads launched from railguns must typically be designed to withstand accelerations of 1,000 Gs or greater.²⁴¹ And, not all the acceleration is in one direction, either. The 1,000 Gs encountered during the railgun acceleration stage is followed by a lesser g-force deceleration due to atmospheric high-Mach ablative effects immediately after railgun launch. For comparison, manned flight is preferentially kept below 12 Gs, although humans can tolerate up to 17 Gs for periods of less than 2 minutes.²⁴² When seated in a contour couch, humans can tolerate more than 20 Gs for short periods of time.²⁴³ Alan Shepard, on his May 6, 1961 sub-orbital flight, experienced 11 Gs on re-entry.²⁴⁴ Ham, the chimpanzee on the earlier Mercury Redstone 2 flight of January 31,

²⁴¹ <http://www.airpower.maxwell.af.mil/airchronicles/apj/spacast3.html>

²⁴² <http://www.hq.nasa.gov/office/pao/History/SP-4201/ch4-2.htm>

²⁴³ <http://www.hq.nasa.gov/office/pao/History/SP-4201/ch4-5.htm>

²⁴⁴ <http://www-pao.ksc.nasa.gov/kscpao/history/mercury/mr-3/mr-3.htm>

1961, experienced an even higher 14.7 Gs during a sub-orbital flight.²⁴⁵ Instantaneous, crash-landing accelerations from 38 to 58 Gs were even tolerated in the infamous NASA “pig-drop” tests of April-May 1959 when four Yorkshire pigs demonstrably got up and walked away after being dropped and accelerated to these levels.²⁴⁶ All these accelerations, though, are miniscule in comparison to what will occur during railgun launches. Railgun launches at 1,000 Gs are compatible only with inorganic payloads consisting of specially designed, and probably expensive items.²⁴⁷

First demonstrated by Michael Faraday around 1831-1832, a railgun conceptually consists of two parallel conductors (hence the term *rail*) through which both a current and a magnetic field are both made to flow at right angles relative to the desired direction of acceleration of an object to be launched by the railgun. (See Figure 5-25.) To conduct the necessary current, a conducting bar that is part of the object to be accelerated and launched is located physically across the two parallel conductors and makes continuous contact with the two rails. As long as the object to be launched does not lose intimate contact with the rail, the launching force is developed solely by the spatial interaction between the flowing current and a fixed magnetic field. (Provided that continuous contact is kept with the rails, no electric field generated forces exist.) Appendix C provides a more detailed theoretical overview of the basic physics of railguns, resulting in the derivation of the key railgun equation, expressing the magnitude of the launching force in Newtons, given by:

$$F = Bli \text{ N}$$

where B is the assumed constant magnetic flux existing orthogonal to the rails, l is the length of the conducting bar in meters (i.e., the distance between the two rails), and i is the current in amps passing uniformly through both the rails and the conducting bar between the two rails.²⁴⁸

The acceleration applied to the object is given by:

$$a = \frac{F}{M} = \frac{Bli}{M} \text{ m/s}^2$$

²⁴⁵ <http://www-pao.ksc.nasa.gov/kscpao/history/mercury/mr-2/mr-2.htm>

²⁴⁶ <http://www.hq.nasa.gov/office/pao/History/SP-4201/ch6-5.htm>

²⁴⁷ In other words, launch cost savings in terms of reducing the cost per launched pound of payload may become less of an issue than the recurring cost of the payloads designed to withstand 1,000 Gs launch acceleration!

²⁴⁸ In contrast to the Appendix, for a non-technical introduction to railguns, without involving any of Maxwell’s Equations, see <http://www.tinaja.com/glib/muse130.pdf>.

where M is the mass of the object being launched. The acceleration is therefore proportional to the magnetic flux, the physical length between the rails, and the current flowing through the conductor. It is inversely proportional to the mass of the object being launched. The velocity is a function of the acceleration acting on the object proportional to the length of the railgun, with longer railguns providing the possibility of achieving higher ‘muzzle’ velocities.

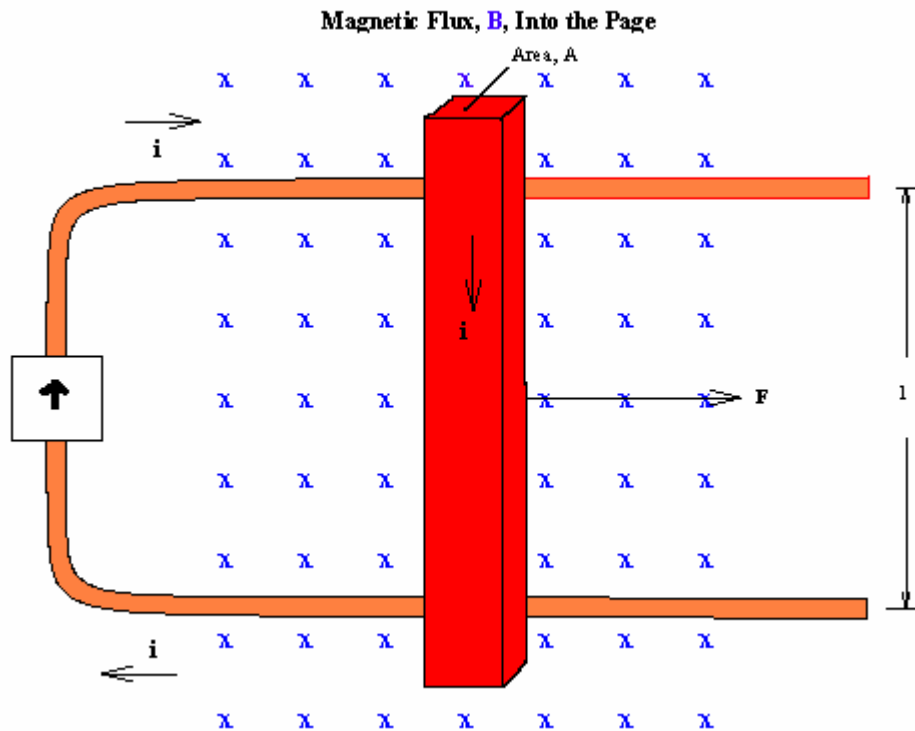


Figure 5-25 Railgun Magnetic Flux & Current Impart Force (F) on Conductor

From these force and acceleration dependence equations, it becomes obvious that to accelerate any object with significant mass quickly, the current i must be increased to rather astounding values, i.e., to values in the tens or hundreds of millions of amps for practical systems having any significant launch capability and a reasonable railgun length. This comes about as the maximum magnetic flux that can be generated is, in practice, limited to rather quickly reached asymptotic limits due to a variety of reasons (permeability limits, air gap reluctances, etc.). The maximum usable gap between the rails, which provides the length factor in the equations above, is likewise limited to the width of the object being launched for reasons of keeping the total drag on the hypersonic-launched object as small as possible in order to maintain a high velocity once the object is clear of the railgun, to reduce ablative effects. To retain an adequate conductor cross-section capable of carrying the extremely high currents required by the

railgun during launch, the mass of the current-carrying conductor on the payload likewise could only be reduced to some fairly large lower limit.

Generating the tens to hundreds of millions of amps required to power a railgun is not an easy task. For example, conventional capacitors have internal series resistances that prevent them from discharging quickly enough to generate dc currents this high. Fortunately, there does appear to be a solution to this problem, at least for smaller railguns. Specifically, one power source that has been proposed for powering railguns is a homopolar generator. This high-current producing power source has also been known as a rotating disc dynamo, a Faraday Disc, an N-Machine, a Unipolar Dynamo, as well as other names over the years.²⁴⁹ These dc power generation devices are capable of generating extremely high current pulses and inherently cannot generate high currents for very long if they are to avoid overheating. Their duty cycle capability is therefore ideally suited for the low duty-cycles required in railguns. Whether they can be scaled adequately to power truly sub-orbital launch-capable railguns remains to be seen. Whatever the power source, generating the extremely high dc currents required for powering practical railguns remains a major obstacle.

Assuming that the railgun is powered properly, the next issue to consider is the length of the rails necessary to achieve the desired velocities required for launch. Escape velocity from earth is approximately 11.2 km/s. Orbital velocities depend on the perigee and apogee of the orbit, but are around 8 km/s for items in orbit at altitudes of 150 miles.²⁵⁰ Launch velocities of around 4 or 5 km/s are typically required for achieving sub-orbital launches. At sea level, this equates to a hypersonic velocity of around Mach 15.²⁵¹

²⁴⁹ This rather obscure dynamo was discovered by Michael Faraday around 1831-1832 and has as its distinctive characteristic the honor of being the only rotating electromechanical power generation device which intrinsically produces dc current without requiring any commutating phase reversal switching (i.e., either mechanically sensed and switched or magnetically sensed and electrically switched). Some of the more famous scientists over the years who have studied this generator include Nikola Tesla and Albert Einstein. Although its operation has mystified scientists since its discovery, over the last decade it has become a topic of study among General Force Theory (GFT) and General Unified Theory (GUT) researchers who hope to unify the various weak and strong forces in the universe with Einstein's Theory of Relativity. One paper that claims to provide at least an explanation for the operation of the homopolar generator using one version of the GFT is available online (see: <http://www.rci.rutgers.edu/~williebo/>). The ultimate fallout from GFT, if the claims of GFT are somehow eventually rationalized with present "real" science, is the theoretical possibility of generating artificial gravity through electrical means by spinning electrons. Such a device would clearly revolutionize space vehicles, and their requisite Spaceports, provided that the likely high currents required for such devices could be met. The reader is cautioned that homopolar generators are intertwined with new-age pseudo-science techno-babble and much of what is published on the World Wide Web is patently wrong (e.g., <http://users.erols.com/iri/homopolar.html>, <http://alexfrolov.narod.ru/n-machine.htm>, and http://www.padrak.com/ine/RS_REF14.html, etc.)

²⁵⁰ <http://users.commkey.net/Braeunig/space/index.htm>

²⁵¹ Mach 1 is 330 m/s (700 mph) at sea level. Assuming a sea level launch, which is probably the least likely for implementing practical railguns, a launch velocity of 5 km/s would be a hypersonic velocity of Mach 15 or so. This launched item is clearly going to cause a sonic boom (a railgun report) at launch. For

Velocities of this magnitude are obtained with a railgun only through accelerating payloads for distances measured in kilometers if g-forces are to be minimized. On the other hand, *if* an acceleration of 1,000 Gs (e.g., 9,800 m/s²) at launch is acceptable, around 500-900 meters of rail could suffice to achieve sub-orbital launch velocities.

To improve launch power efficiencies, it would also be beneficial if these rails were placed in a vacuum. If so, then the end of the enclosed, air-evacuated rails, positioned inside of a launch tube, would need to terminate against a reusable sealing window pointed at the sky. It would also be necessary to pump down the vacuum with roughing pumps, which, considering the hundreds of meters of length of track required and of the likely diameter of possible payloads, would require a significant number of hours of pumping even for a rather large number of vacuum roughing pumps used prior to the initial launch. However, if a large, quickly re-sealing window were used at the end of the rail, a minimal amount of air would enter the railgun track launch tube during each launch, thereby reducing the amount of time required to pump the launching tube back down between launches, improving the launch responsiveness of the railgun launcher.

Assuming that the desired velocities can be achieved within the acceleration, vacuum, and minimum length of rail limits desired for the railgun launcher, the next question is the determination of the direction for launch. First, to avoid introducing additional high g-forces onto payloads during launch, above the already high 1,000 Gs due to railgun acceleration alone, there could be no concave-up railgun track curvature used (e.g., it would be desired to avoid the use of any “J”-shaped track laid on its side). Straight railgun tracks would be most desirable. To avoid having to make large changes in tangential velocity vectors at altitude and wasting fuel, such as when launching upper stages of orbital payloads, long, naturally-sloping terrain would be most desirable for locating the railgun launcher. For low-g launch railguns, such terrain exists only a few places on earth at high elevations near the equator. Low-g acceleration railgun launch platforms would therefore be compatible with only a small subset of all possible Spaceport locations. High-g railguns, on the other hand, could be placed at most Spaceports. The noise from the hypersonic payload streaking into the sky would have to be managed through placing the railgun launcher and the Spaceport in non-populated areas. With spaceliner concepts, whereby sub-orbital and orbital craft take off and land at reduced speeds, the need for noise abatement could be more like the methods used for existing airports. For a railgun launcher, however, only truly remote Spaceports could be used to reduce in advance the objections that would otherwise arise in populated areas from sonic booms sounding each and every launch.

The inherent dc resistance of the rails, proportional to rail length, reduces the current that can flow through the rails for any given dc voltage. Generating high dc currents through the rail while overcoming this rail resistance requires a significantly high voltage be applied. However, upon applying the high dc voltages needed to generate high currents,

Mach velocity background information, see the information at NASA Glenn Research Center <http://www.grc.nasa.gov/WWW/K-12/airplane/mach.html>.

an inherent danger arises. If, while traveling down the rail, the current conductor on the payload is even momentarily disconnected from continuous contact with the rail, a large arc will develop. Welding of the conductor to the rail, or, at the very least, severe pitting of the rail and of the conductor on the payload, is the most common outcome when this happens. This characteristic immediately begs the question of what happens at the end of the rail, where clearly the object ceases contact with the rail? A disconnection obviously occurs there, and the rail clearly runs the risk of severe damage during every launch. The likely result is that there will be excessive wear and shortened lifespan for every railgun built that does not contain replaceable end sections.²⁵²

Furthermore, based on construction practicalities and on plasma-induced conduction occurring due to localized heating of the contact between the rail and the object being launched, and the maximum speed at which a plasma flame can be pushed through an air atmosphere, or that an object can be propelled in a hypersonic flight profile through the lower atmosphere, a maximum velocity of around 4-6 km/s is about the limit that can be obtained under terrestrial conditions. Because of this ‘speed limit’, orbital flights would be possible only if the railgun-launched payload carried its own booster that would ignite at the top of the sub-orbital ballistic trajectory. But, such added mass could quickly become more than any particular size railgun could launch to high sub-orbital altitudes. Considering this, it is likely that railguns would be most useful for launching sub-orbital flights, only.

This section has explored the difficulties of:

- Generating hundreds of millions of amps of current, at high dc voltage
- Passing launch payloads down microscopically smooth, low-resistance rails, as required for launching even very tiny satellites
- Maximum velocities of only 4-6 km/s, suitable for sub-orbital launch only

These difficulties all combine to limit the usefulness of railguns for launching satellites. Although these difficulties could be overcome, it is not likely that all these difficulties will be overcome and the sub-orbital and orbital launching of items of any significant mass will result within the span of time identified as germane to the scope of this investigation. For that reason, barring any major disruptive scientific breakthroughs in high-voltage, extremely high-current dc power generation or in high-temperature superconductors; the widespread and general use of railguns in the near future (i.e., within 15-30 years) at Spaceports does not warrant additional study in terms of their likely non-impact on general Spaceport and Range designs.

²⁵² The wear and pitting at the very end of the rail could be resolved through the use of replaceable rail-ends, designed to be quickly, cheaply, and easily replaced between launches. No more than a few meters of replaceable rail would likely be required for regular replacement at the end of the rails after each launch. The wear and pitting along the rails, however, due to payload bounce (i.e., the pogo up and down effects of the payload bouncing on the rail during launch) would not be as easy to overcome. Whether or not to include this end of the rail within the vacuum of the launch tube would need to be carefully studied.

5.5.6 Space Cannon

Although railguns theoretically can launch small payloads into orbit, as discussed previously, the use of conventional cannons to accomplish the same goal should not be dismissed out of hand. After all, unlike railguns, cannons require no breakthroughs in electromagnetics or high-current power supplies to launch items into space. Furthermore, cannons have been capable of reaching the edge of space with small projectiles since World War I. Serious research has been underway for over eighty years to develop cannons with the ability to launch larger payloads into space. Regrettably, since 1967, in spite of considerable long-standing research, cannons have not generally been considered suitable for providing access to space for small payloads and have not garnered recent support within the United States. Nonetheless, as investigated in this section, considerable merit remains in using large cannons for special purpose sub-orbital and orbital launch applications.

The key characteristics of cannons for launching small payloads into space are that they:

- Use chemically powered explosives to launch payloads (in place of chemically powered rockets or difficult-to-generate high intensity electromagnetic fields)
- Can provide quick launch-responsiveness for launching small payloads into common, largely similar orbits
- Can be environmentally friendly
- Can achieve low launch costs
- Expose payloads to accelerations in excess of several hundred Gs for practical-sized cannons, limiting their use to especially designed, small, inorganic payloads
- Generate loud reports at launch, limiting cannon launchers to use only at remote Spaceports where noise is not an issue
- Require no dc launch currents in the hundreds of millions of amps at extremely high voltages, in contrast to railguns
- Often have limited launch trajectories available that are highly dependent on the final azimuth and elevation selected for installation of the final cannon bore, and remain fixed after the final installation of the cannon

Because of these theoretical advantages and long development history, cannons are often considered for launching nano-satellite payloads from future Spaceports. Unfortunately, cannons do not engender the same support as conventional rockets, and, instead, any discussion regarding using them to provide low-cost access to space inevitably provokes archaic 19th century images of a Jules Verne science fiction novel instead of promoting a technology of the future. Paraphrasing the words of a more modern science fiction author, Arthur C. Clarke, who one stated space elevators (to be discussed later) would probably never be built until about fifty years after people stopped laughing about *them*, giant cannons for launching small objects into space will likewise probably never be

completed until about twenty years after people stop laughing about them.²⁵³ In spite of a bad image, however, cannons have long been capable of launching small projectiles and payloads into space, and could easily provide a very low-cost launch capability for launching future micro-satellites into space.

The first mathematically-sound accessible treatment for using cannons to launch items into space dates to 1687, when Sir Isaac Newton published his *Philosophiae Naturalis Principia Mathematica*, generally known today as the *Principia Mathematica*, or, more often, just the *Principia*. Newton worked on his *Principia* from about 1684 through 1686. It was largely the outgrowth of practically applying the calculus of fluxions (which today we call the differential calculus, or derivatives) he had developed from 1665 to 1666 during a forced holiday from Cambridge during an outbreak of the plague.²⁵⁴ In the *Principia*, Newton wrote:

“Imagine a mountain so high that its peak is above the atmosphere of the earth. Imagine on top of that mountain a cannon that fires horizontally. As more and more charge is used with each shot, the speed of the cannonball will be greater, and the projectile will impact the ground farther and farther from the mountain. Finally, at a certain speed, the cannonball will not hit the ground at all. It will fall toward the circular earth just as fast as the earth curves away from it. In the absence of drag from the atmosphere, it will continue forever in an orbit around the earth.”²⁵⁵

This earliest description of an orbital trajectory used a cannon to achieve it, although arguably the use of the cannon was more for the pedantic purpose of explaining in layman’s terms what an orbit was, instead of actually proposing a cannon for launching items into space. Newton was essentially doing a *gedanken* experiment (i.e., a thought experiment), solely for the purpose of reasoning theoretically. His *gedanken* experiment just happened to include a cannon for connecting with the reader.²⁵⁶ Nonetheless, Newton’s investigation was the first ever to consider using a cannon to launch an item into orbit.

Newton’s mathematics also was the basis for the next widely known suggestion for a space cannon that appeared in Jules Verne’s 1865 novel titled *From the Earth to the*

²⁵³ Ziemelis, Karl, *Space Elevators Get a Lift*, Space Daily, London, May 2, 2001, <http://www.spacedaily.com/news/future-01f.html>, retrieved 8 May 2002. Arthur C. Clarke once stated, "The space elevator will be built about 50 years after everyone stops laughing".

²⁵⁴ <http://www.hao.ucar.edu/public/education/sp/images/newton.html>

²⁵⁵ <http://www.friends-partners.org/mwade/lvs/newannon.htm>

²⁵⁶ *The Jargon Dictionary*, online edition, <http://info.astrian.net/jargon/terms/g/gedanken.html> which is available as a snapshot in time in conventional book form as *The New Hacker’s Dictionary*, 3rd Edition, compiled by Eric S. Raymond, MIT Press; ISBN: 0262680920; 3rd edition (October 11, 1996).

Moon. In this novel, Verne writes about a moon cannon that is situated in Florida, presaging the Kennedy Space Center (KSC) of today. Verne situated his fictional spaceport only 132 miles from where KSC is today. Numerous parallels have been drawn from comparison between his novel and the actual launch of Apollo 11 in 1969.²⁵⁷ What is interesting is that Verne based his novel on the best scientific thought of his day, and the mathematics had not changed since the days of Newton. Because of Verne's detailed engineering estimates and analyses, many of his estimates, and even his choice of a Spaceport location at approximately 28 degrees north latitude, were particularly accurate, even though there were certainly other issues that Verne did misjudge. For example, Verne conveniently neglected launch acceleration, into the thousands of Gs, which would have proven instantly fatal to human passengers. Nonetheless, in spite of numerous slight scientific shortcomings, Verne's novel became a virtual blueprint followed by many of the actual participants in the early US space program, as it was the first detailed effort to explore many of the same issues that were ultimately addressed in actuality.²⁵⁸

The first major step in bringing the concept of a space cannon into reality was *The Paris Gun* of World War I (Figure 5-26). Known variously as *Big Bertha* (in apparent confusion with a separate 'gun' called *Big Bertha* that was actually a large mortar), *Lange Max* [Long Max], and *Kaiser Wilhelm Geschuetz* (i.e., Kaiser Wilhelm's Cannon), this gun used a 180 kg (400 lb) powder charge to hurl 120 kg (265 lb) shells (with explosive payloads of 7 kg) to distances of 140 km (87 miles), with the shells traversing the very edge of space at 40 km (25 miles) altitudes. Aimed higher, for altitude instead of distance, the 120 kg (265 lb) shells could be fired to altitudes of 65 km (40 miles), which were clearly altitudes into space. The psychological impact of *The Paris Gun* was greater than its military effectiveness. From March through August 1918, three of the giant guns lobbed a total of 351 shells at Paris, killing 256 and wounding 620. As an effective weapon, *The Paris Gun* was largely a failure, lobbing only 7 kg explosive payloads, and requiring re-boring of badly eroded barrels from a diameter of 21 cm to 24 cm after only 65 shots per barrel. Until the V-2 flights of World War II, though, the altitudes at the very entrance to space reached with *The Paris Gun* would not be equaled.²⁵⁹

After *The Paris Gun* of World War I, it was not until World War II that the next major step was taken in developing a practical space cannon. Less well known than the V-1 and V-2 *Vergeltungswaffen* (i.e., vengeance, or reprisal, arms/weapons/branch of service) of World War II, a third German weapon was developed known as the V-3, (i.e., *Vergeltungswaffe-3*). The V-3 was also known officially as the *Hochdruckpumpe* [High

²⁵⁷ <http://www.friends-partners.org/mwade/lvs/julongun.htm>

²⁵⁸ Well-worn copies of the novel are still in the Kennedy Space Center library to this day in the NASA Headquarters building. (May 2002.)

²⁵⁹ <http://www.friends-partners.org/mwade/lvs/parisgun.htm>

Pressure Pump], *HDP*, as well as non-officially as *Fleissiges Lieschen* [Diligent Little Lisa; literally, Diligent Listened], and *Tausend Fussler* [Thousand Kicker].) This super gun featured a 140 m (460 ft) long cannon capable of delivering a 140 kg (308 lb) shell over a range of 165 km (102 miles), achieving a muzzle velocity of 1500 m/s. Construction began on a bunker for the cannons in September 1943 at Mimoyecques, France, based on earlier successful tests conducted during April-May 1943 of a 20mm (0.8 inch) prototype at Misdroy (Miedzyzdroje), Poland. Based on the test results in Poland, Hitler believed this could be a third terror weapon to supplement the more infamous V-1 and V-2. He ordered fifty of the guns to be built in concrete bunkers in France with which to bombard London. Fortunately, Allied bombing damaged these bunkers before the V-3 guns (Figure 5-27) went into operation, and no full-size V-3 guns were ever completed.

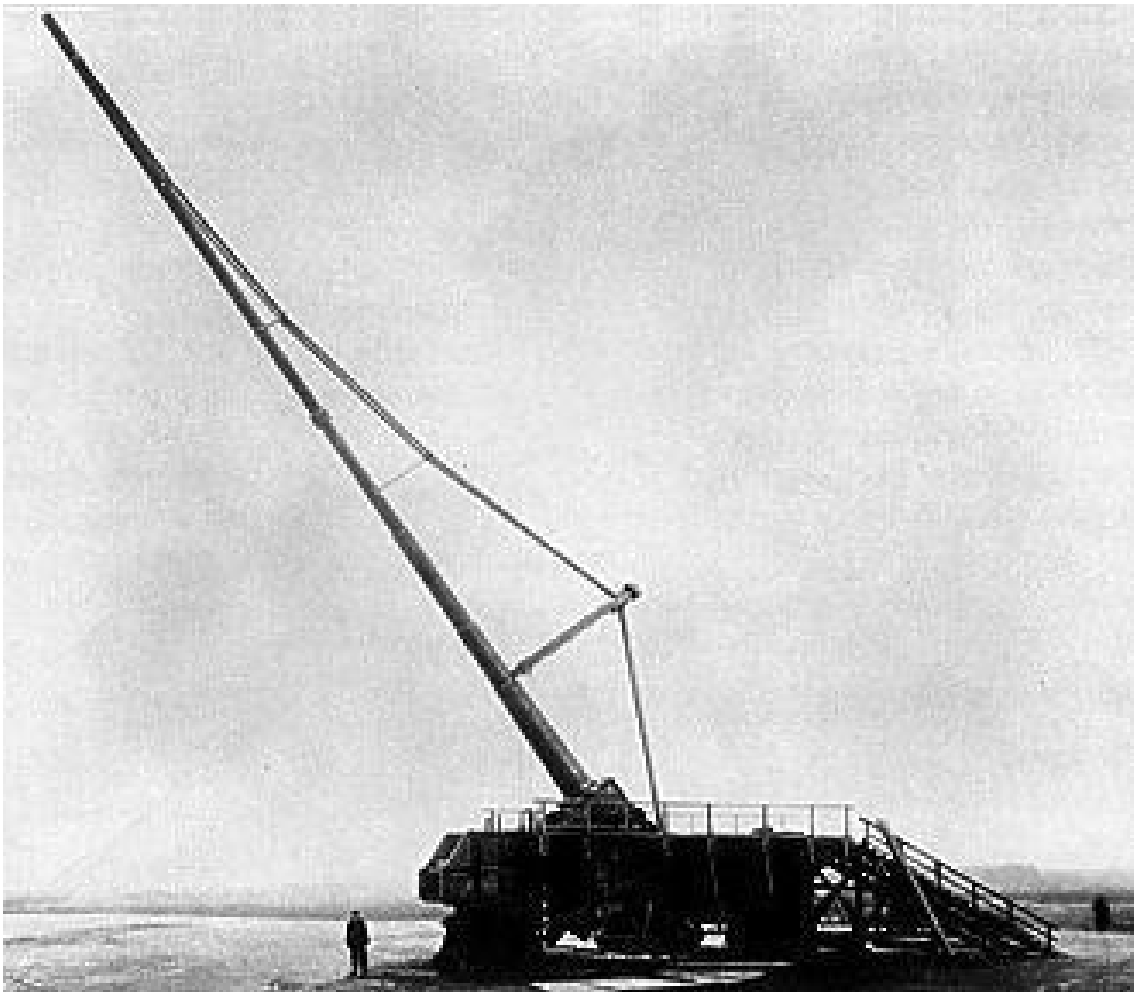


Figure 5-26 Paris Gun (WWII)



Figure 5-27 V-3 Gun (WWII)

Two shorter-length (45 m (147 ft) long) V-3 guns were built at Lampaden about 13-kms from Trier in support of the Ardennes offensive (i.e., the Battle of the Bulge) in December 1944. The Lampaden guns were used from December 30, 1944 through February 22, 1945 and fired a total of 183 projectiles into Luxembourg city from a distance of 42.5-kms, of which 143 actually exploded, killing ten and wounding thirty-five. With the Allies advancing rapidly, the guns were hastily disassembled starting February 22, 1945. The disassembled guns were later captured by the Allies and sent to the Aberdeen Proving Grounds in Maryland for detailed test and evaluation, where they were eventually scrapped in 1948. Although the total military impact of the V-3 guns at Lampaden on Luxembourg was minimal, they were used to attack an already liberated Luxembourg, which had been freed by the United States Army in September 1944. Loss of life is always sad, but for the citizens of Luxembourg, who had already been liberated from the Nazis, and no doubt were starting to believe the war might actually be over for

them, the use of the V-3 was particularly cruel. Of the ten killed, four died while attending evening Church services when a V-3 projectile struck the Church belfry.²⁶⁰

The design of the V-3 super gun was ingenious. Electrically activated charges were used to overcome pre-mature explosions of the distributed charge inside the gun bore caused by expanding gases from the base charge moving ahead of the shell and igniting auxiliary charges and retarding the shell. To further control uncontrolled detonations, and provide for a modular design, angled lateral combustion chambers were placed at regular distances along the gun's bore. Because it was a modular weapon with replaceable lateral chamber sections, its design avoided the re-boring maintenance issues seen with *The Paris Gun* of World War I. Had the full-size V-3 guns been finished, it is likely that they would have routinely launched projectiles into space in the course of bombarding London.

The next period of development for space cannons was largely the result of the work of just one man, astrophysicist Dr. Gerald V. Bull of Canada. Starting in the 1950's through March 1990, he single-handedly dominated the large cannon and artillery scene worldwide. As a professor at McGill University in Montreal, his early research attracted the attention of the Canadian Armament and Research Development Establishment (CARDE) in the mid-1950s for using guns as small as 3-in (76 mm) to launch sounding probes into the very edge of space. By the late 1950s, Dr. Bull's work with CARDE had progressed to the point that it had attracted the attention of the US Army's Ballistic Research Laboratory (BRL), and this, in turn, led to joint feasibility studies during the early 1960s at both CARDE and BRL. The result was a 5-inch (127 mm) gun-launch system later incorporated into a larger joint US-Canadian funded program known as the High Altitude Research Program (HARP) - the 'HARP' acronym being considered especially appropriate as angels traditionally are considered to fly at high altitudes and obviously associate with harps. Initially launching items from the island of Barbados, Dr. Bull's small 5-inch (127 mm) guns fired projectiles to altitudes of over 70 km (43.5 miles), and 7-inch (178 mm) guns (Figure 5-28) later fired projectiles to nearly 100 km (62 miles). Later, in Barbados and Arizona, larger 16-inch (406 mm) HARP guns were constructed. On 19 November 1966 the sixteen-inch gun in Arizona fired a 185-lb (84 kg) payload to an altitude of 111 miles (180 km). Ultimately, the sixteen-inch HARP gun was intended to launch a small three-stage rocket carrying a 22-lb (10 kg) payload into space.

The five-inch HARP gun-launch systems were used for launching projectiles weighing up to 10 kg (22-lb) to altitudes of up to 76 km (47 miles). More typically, the application was to launch to altitudes of up to 40 miles (65 km) typical 2-lb (0.9 kg) scientific payloads that were ejected at apogee. Included in the two-lb ejected payloads were reflective chaff, used for radar tracking of upper wind speeds, as well as sensors with radio telemetry capability, used to transmit measured upper atmosphere temperature and humidity data. Taken in total, the data collected expedited the quick development of new

²⁶⁰ <http://www.nat-military-museum.lu/pageshtml/museumspecial.html>

supersonic atmospheric vehicles and missile systems in both the United States and Canada. Altogether, these scientific payloads allowed considerable low-cost research into the properties of the upper atmosphere; achieving results impossible to achieve with lower-altitude balloons and aircraft.²⁶¹ In contrast to expensive sounding rockets, which could reach similar altitudes (or even higher), the five-inch gun-launch platforms achieved a typical launch cost of only \$300- \$500 per launch.²⁶²



Figure 5-28 HARP 7-Inch Gun

The five-inch HARP gun-launch system was based on modified 120 mm (4.75 in) T123 service guns, modified to a smoothbore barrel configuration, and having a welded-on extension to the barrel to extend the bore to a total length of 8.9 m (29 ft). Six launch sites for the five-inch HARP gun-launch systems were set up at Barbados; Highwater, Quebec; Ft. Greely, Alaska; Wallops Island, Virginia; White Sands, New Mexico; and Yuma Proving Ground, Arizona. Over three hundred flights were achieved over five years.

²⁶¹ No doubt, what was truly high ‘bang for the buck’.

²⁶² <http://www.friends-partners.org/mwade/lvs/Sinrpgun.htm>

For higher flights, and larger payloads, a fixed sixteen-inch gun-launch installation was first installed at Barbados, with the Range extending over the Atlantic for safety. A surplus 125-ton sixteen-inch diameter gun from the US Navy was modified to extend its standard 20 m (65.6 ft) barrel to 36 m (118 ft). The gun was further converted to smoothbore; eliminating the rifling that would otherwise have spun the payload to unacceptable spin rates. From 1962 through 1967, Bull launched over 200 atmospheric probes to altitudes of up to 180 km (111 miles). To increase the altitude by just four additional miles, a pumping system was even used to pump down most of the air from the gun barrel. An airtight cover over the muzzle was then blown away during the shot.²⁶³ The lack of mobility, however, greatly limited the usefulness of the sixteen-inch gun launch system to provide atmospheric data at widely dispersed geographic locations. The sixteen-inch guns were only installed in Barbados and Arizona. As a result, after the five-inch guns and sixteen-inch guns had demonstrated their usefulness for upper atmospheric research, a portable seven-inch HARP gun-launch system was developed to reach altitudes in excess of 100 km (62 miles) with three times the payload capacity of the five-inch HARP gun. This represented the optimal trade between capability and the upper size limit imposed by portability. The seven-inch gun barrel was 55 ft (16.8 m) long. Two of the seven-inch guns were built. A total of sixty operational flights were achieved over a three year period for the seven-inch HARP, prior to the sudden and unplanned disbandment of the entire joint US and Canadian HARP research in 1967 due to severely strained relations between the two countries over the involvement of the United States in the Viet Nam war.

Despite the breakdown of relations between Canada and the United States, Dr. Bull negotiated the right to retain title to the assets of the HARP program, becoming a consultant to artillery manufacturers worldwide, and formed a company known as Space Research Corporation. Furthermore, because Bull's lack of American citizenship became a hindrance in the Pentagon arms trade, and the Canadian Government had tried to dissuade Dr. Bull from supporting the U. S. Navy in the development of long range shells for shelling North Viet Nam from far at sea, Senator Barry Goldwater of Arizona introduced an unusual bill by which Dr. Bull became an American citizen by an act of Congress.²⁶⁴ This procedure was a rare honor, previously given only to Prime Minister

²⁶³ <http://www-istp.gsfc.nasa.gov/stargaze/Smartlet.htm>

²⁶⁴ Yuma Proving Grounds, Arizona, where the HARP research was being conducted in the United States was in Senator Goldwater's home state. Sen. Goldwater, a powerful conservative Republican, was also known for his strong support of the U.S. military and of weapons of all kind, including, it might be added, nuclear weapons – a stand that probably cost him the Presidency when he ran for President in 1964 against President Johnson. An infamous Democratic National Party TV ad that ran only one time, depicting a girl plucking petals from a daisy, with a countdown, followed by a giant mushroom cloud, certainly played a factor in his defeat. Likewise, Barry Goldwater's 1964 speech accepting the Republican Party's nomination to run for president, in which he responded to repeated accusations of "extremism" with: "I would remind you that extremism in the defense of liberty is no vice! And let me remind you also that moderation in the pursuit of justice is no virtue!" certainly played a factor, as well. Democrat Lyndon Johnson soundly trounced Republican Goldwater in the presidential election after responding with the quote: "Extremism in the pursuit of the Presidency is an unpardonable vice. Moderation in the affairs of the nation is the highest virtue." [

Winston Churchill of England and the Marquis de Lafayette of France. Unfortunately, one of Dr. Bull's customers later was South Africa, and this relationship, plus his awarded American citizenship, landed Dr. Bull in prison for six months in 1980 for illegal arms dealing, in what was clearly an unintended side effect of his appointed American citizenship.²⁶⁵ The result, upon his release from prison, was that Dr. Bull moved once more, this time to Europe; where he could continue to develop designs for artillery customers worldwide without the interference of the American *or* Canadian governments. One of his customers was the Iraqi government, from whom he received a contract for the *Project Babylon* super gun. This gun was designed to launch payloads into orbit, as well as to launch warheads over extreme ranges.

The basic design of the *Babylon* super gun was displayed at the Baghdad International Exhibition for Military Production in May 1989. The barrel of the super gun was 156 meters long, with a diameter of 1 meter. Weighing 2100 tonnes, and fixed in azimuth and elevation, the gun would have been a minimal threat had it been aimed in an innocuous direction. But, unfortunately for Dr. Bull, the gun was to be constructed at a site in Iraq and aimed at Israel.²⁶⁶ Clearly, though, the super gun was not a pressing threat to Israel, as it was fixed, unable to be moved, and would have been an easy target for cruise missiles or even a single air attack prior to being completed and becoming a real threat to Israel. The Israeli government repeatedly warned Dr. Bull to terminate his contract with Iraq. Dr. Bull ignored the warnings from the Israelis, and then made his fatal mistake. He agreed to assist Iraq further in designing the nose cone for a multi-stage multi-warhead missile using clusters of Scud Rockets, simultaneous to his ongoing work in developing the *Project Babylon* super gun. As a result of Dr. Bull's refusal to stop providing technical support for the Iraqi projects, and especially of his MRV nose cone design work for the Iraqis, agents (presumably of the Mossad) assassinated Dr. Bull in a professional hit outside his apartment in Brussels, Belgium in March 1990. Dr. Bull's body was found with five shots to the back of his head. No one heard the shots. Nor was anyone ever arrested.²⁶⁷

After 'Desert Storm' (i.e., the Gulf War), United Nations disarmament teams discovered (in 1991) that the *Project Babylon* super gun had not only been under construction, but had also been aimed directly toward Israel, 300 miles distant. At this range, the gun would have easily been able to fire projectiles with various payloads (chemical, biological, etc.) directly into Israel from Iraq. To prevent the gun from being finished,

http://www.capitalismmagazine.com/1998/july/july98_bury_extremism_gw.htm *Capitalism Magazine*, July 1998, retrieved 10 May 2002.] Dr. Bull's supporter and sponsor, Senator Goldwater, retired from the Senate in 1987, just three years before Dr. Bull was assassinated at his home. Retired Senator Goldwater himself died May 29, 1998 at home in his beloved Arizona of natural causes.

²⁶⁵ <http://www-istp.gsfc.nasa.gov/stargaze/SGBull.htm>

²⁶⁶ <http://world.std.com/~jlr/doom/bull.htm>

²⁶⁷ <http://world.std.com/~jlr/doom/bull.htm>

the U.N. team proceeded to disassemble the *Project Babylon* site. Likewise, and only a few weeks later, eight pieces of the barrel were intercepted in Britain, marked as chemical industry components. Other pieces of the gun were shortly discovered by customs officials and seized in Greece and Turkey. Although the loss of innocent lives was avoided in Israel through the dismantling of the gun, the dream of Dr. Bull, to achieve a gun-launch system for launching payloads into space, died with Dr. Bull, as no action was undertaken to recover the pieces of gun for removal to the United States.²⁶⁸

Since 1990, research into giant space cannons has languished. Sparse reports have emerged that the Chinese are working on a launch system similar to the *Project Babylon* gun, perhaps as an outgrowth of Dr. Bull's earlier work consulting for them during the 1980's. According to some reports, this super gun has a 22m (72 ft) long barrel and is capable of launching projectiles to Taiwan. No detailed development information has been publicly announced since Dr. Bull's death.²⁶⁹ On the artillery front, announcements have emerged in November 2001 that South Africa still leads the world in its howitzer range. Building on its Dr. Bull-designed system from the 1980's, which achieved an operational 39 km range versus the then NATO forces' range of 18-30 km, South Africa's G6 155 mm howitzer is currently being revamped to achieve ranges of up to 70 km, thereby continuing their lead on howitzer technology. Dr. Bull's legacy lives on.²⁷⁰ Clearly, giant cannons could provide an interesting method for the low-cost launching of small satellites. Further, the design of the projectiles and of the satellites themselves, to withstand the launch accelerations, could be done. Altogether, the total budget for Dr. Bull's early work was only around \$10 Million (US). For a small fraction of the cost of developing a new space launch vehicle, a cannon launch system could be designed, fabricated, and assembled. Perhaps, if the laughter analogous to that described by Arthur C. Clark has stopped, such a system could become a reality within the next twenty years, providing low-cost, niche-market access to space for nano-satellites.

5.5.7 Space Elevator

The Space Elevator (SE) is an age-old disruptive technology concept for a geostationary (GEO) orbiting platform tether to provide extremely low-cost access to space. To date, work on this advanced concept has largely been coordinated at the NASA Marshall Space Flight Center in Huntsville, AL.²⁷¹ The most recent Advanced Space Infrastructure Workshop on the SE was held June 8-19, 1999 by the Flight Projects Directorate in cooperation with the Advanced Projects Office, Office of Space Flight, NASA

²⁶⁸ For more information on Dr. Bull, see *Bull's Eye--the assassination and life of supergun inventor Gerald Bull* by James Adams, 317 pp., NY Times Books 1992.

²⁶⁹ Jane's Defence Weekly, Friday, February 10, 1995.

²⁷⁰ Jane's. WWW.JANES.COM, <http://www.janes.com/press/pc011109.shtml>

²⁷¹ http://flightprojects.msfc.nasa.gov/fd02_elev.html

Headquarters, Washington, DC and the Advanced Space Transportation Program, NASA Marshall Space Flight Center in Huntsville, AL. A summary report was issued in 2000, and the key points of this report are summarized in the following pages.²⁷²

The easiest way to visualize this low operating cost approach to space is through the following artist's concept by Pat Rawlings, Science Applications International Cooperation, prepared as part of the NASA summary report from 2000 (Figure 5-29). The viewpoint for this rendering of the concept is from a vantage point aboard the GEO transfer point looking back along the length of the elevator structure toward earth.



Figure 5-29 Space Elevator Concept

Propelled by high-speed electromagnetic motors, aerospace vehicles traverse the length of the elevator, transferring passengers and cargo between geostationary earth orbit and the surface of the earth. As envisioned in this artist concept, six vehicular tracks would surround a high-strength tubular core structure constructed from future advanced carbon nanotube material. Three of the tracks would be dedicated to maintenance vehicles necessary to maintain the elevator; leaving just three tracks for passengers and cargo. As there would need to be a mechanism for adjusting the center of mass of the geostationary station to exactly geostationary altitude to provide the adjustments necessary to set

²⁷² http://flightprojects.msfc.nasa.gov/pdf_files/elevator.pdf

exactly the GEO length of the elevator, large spherical structures containing reels of high strength cable are depicted.

The primary economic driving force behind the SE concept is the very low-cost that would be achievable for putting payloads into orbit. An estimated energy of only 14.8 kWh/kg would be required to achieve GEO altitudes using the SE. Assuming an electrical energy cost of around \$0.10/kWh, launching a mass into GEO orbit would cost only around \$1.48/kg. For comparison, a cargo equivalent to an average space shuttle cargo of 12,000 kg would cost only around \$17,760 for launch into orbit; in contrast to the approximate cost of \$1,000,000 to \$2,000,000 for launching the shuttle today (depending on how exactly one tallies up the total). Similarly, launching an individual person with luggage, for an assumed total mass of 150 kg, would cost only around \$222. The price for such a ticket, even assuming a seven or eight times markup to around \$1,500 for commercial profit, would be far less than the \$20,000,000 reportedly paid to the Russians by South African millionaire Mark Shuttleworth for a ten day journey to visit the International Space Station in April-May 2002.²⁷³ Such a radical reduction in launch costs means that an SE would open the door to a fundamental shift in the economic equation for using space.

The concept for building a tower to the heavens from the surface of the earth is ancient. Moses, writing in about 1450 B.C., described an early attempt from around 2100 B.C. by the Babylonians, to build such a structure in ancient Mesopotamia known as the Tower of Babel. Another similar concept was Jacob's Ladder, a staircase or ladder ascending to the heavens, which dates to around 1900 B.C. The writer Tsiolkovski, writing in 1895, described a similar concept in his *Speculations about Earth and Sky and on Vesta*. Obscure reports regarding the concept appeared throughout the 1960-1975 era. Arthur C. Clarke, building on the ideas of these obscure reports, wrote his 1978 science fiction novel *The Fountains of Paradise* that greatly popularized the SE concept in the public's eye.

None of these earlier writings came close to addressing the engineering and material strength difficulties implicit in building an SE, nor do they provide any sound consideration of the technological details required simply to fabricate the pieces required for such a structure. To be geostationary, such a structure would have to be 36,000 km long, as a minimum, neglecting mass counterbalancing. Then, to avoid collisions with aircraft or other aerospace vehicles, maneuverability requirements would require even a slightly longer structure capability, with control mechanisms for bending, twisting, or otherwise maneuvering the SE track to avoid collisions with aircraft, spacecraft, or orbital debris. To allow easy movement of the ground segment, and to reduce the risk of

²⁷³ According to many reports, \$20,000,000 almost exactly matches the actual cost of launching the Soyuz TM-34 spacecraft into orbit to rendezvous with the International Space Station (ISS). Dennis Tito, the first space tourist, supposedly paid the same fee in 2001 for his trip into space with the Russians. The tourism fee charged therefore largely reimburses the Russians' expense of launching a spacecraft to the ISS, which would have to go even if not supported by tourism. Incidentally, Mark Shuttleworth returned to earth in a different Soyuz spacecraft, a TM-33, which had served as a lifeboat for the ISS since last year.

such a structure failing and falling from the sky, as well as to accommodate political needs for a multi-national effort, the earth station would likely have to be floated at sea, on the equator. Likewise, to reduce energy usage requirements, it would be extremely beneficial to recover the potential energy contained in returning payloads during descent braking, to achieve as efficient a total system as possible.

Two approaches have been considered for achieving a center of gravity at GEO for the entire SE structure, providing a counter-balance to counter the weight of the system and to prevent it from falling to earth. First, if an asteroid counterbalance were used, a total length of approximately 47,000 km of SE track would be needed to “sling” an asteroid at near escape velocity around the earth as needed to counter the mass of the SE structure. Alternatively, if no asteroid counterbalance were used, then a total length of approximately 144,000 km of SE track would be required. Clearly, between these two possibilities, an asteroid counterbalance would be preferred to reduce the construction difficulties associated with the construction of the SE in the most cost-efficient manner possible.

Obviously, though, the total tensile strength of the space track is a major issue that must be overcome if the SE is to become a reality. The strength required for the core structure is believed to be around 62.5 GPa (Giga Pascals). High strength steel has a yield point of only slightly more than 0.3 GPa; it clearly is too weak and heavy for the central core. Carbon nanotubes, on the other hand, have already demonstrated strengths in excess of 100 times that seen for steel at a fraction of the mass. This performance, at least for small samples, is clearly in the same range as the strength of 62.5 GPa required for the SE. Of course, many properties of materials do not scale up in simple proportional terms. Just because nanotubes in a test tube exhibit the necessary properties does not prove the supposition that nanotubes by the ton would have the same needed physical properties, nor that they could even be fabricated in space and installed in a continuous strand for more than 36,000 km.

Due to the continual mind-numbing scanning, inspection, and routine repair and maintenance of a 47,000 km, or longer, track; the construction of the SE, as well as the continual maintenance, would require considerable advancements in autonomous robotic systems. Yet, without continual repair and maintenance, it is not likely that the SE could survive for long even if it were built. Micrometeoroid damage would bring the SE down in a matter of only a few years, even if a massive strike by a larger meteoroid were somehow avoided. To avoid damage from larger meteoroids, a self-defense system comprised of lasers, or another similar vaporizing technology, would likely be required to protect the SE.

These dangers, however, assume natural catastrophes, only. Clearly, considering the World Trade Center complex was a highly prized target of terrorists, the World Space Elevator would become an even higher prized target. As such, it would be forever the goal of terrorists worldwide to destroy this structure, if it were to be built.

Fortunately, the physics of the SE do mitigate some threats. Hurricanes, for example, cannot exist at the equator, but instead form at some minimum distance from the equator, and then proceed to travel away from the equator on their recurring journey to colder waters. Overall, weather around the equator is typically balmy and benign throughout the year. On the other hand, tsunamis could be a potential threat, as earthquakes far removed from the equator could create giant waves. Likewise, icing could be an issue at altitudes of 4-5 km above the equator along the SE. At higher altitudes, atomic oxygen could be a threat, potentially causing erosion of the SE tracks and SE vehicles. UV radiation would likewise be a danger that would have to be addressed, to prevent chemical changes or structural weakening of the SE track. Above the atmosphere, space debris would need to be considered. Even small paint chips traveling through space could pose a threat to eroding the SE track. As tracking technology evolves, the risk from larger items could largely be mitigated. However, items in the range of diameters from 1 mm to 10 cm could prove difficult to track, dodge, or even destroy in a timely fashion. Consider especially the uncommon event of either a seasonal meteor storm (e.g., the Leonids of November or similar) or of orbiting space debris. Altogether, there will be considerable dangers that must be addressed and overcome before the SE can become a reality.

Whether it would be desirable to have a rocket-assisted lift capability, to lift the upper part of the SE to a higher orbit if an unintended break did occur, or whether it would be better to steer the failed structure into a controlled, destructive re-entry into a remote part of the ocean are decisions that would have to be made while designing the system. Protecting passengers and cargo, in the event of an SE failure, would likewise require an assortment of techniques. Perhaps an automated pilot capability for the elevator vehicle, as well as a high Mach thermal protection system and/or a simple ablative system, would need to be employed for use in what would presumably be a one-time occurrence in the event of a catastrophic track break. Presumably, designing in the capability for achieving a safe return of an SE vehicle from anywhere along the tether would be preferable to assuming that such a failure would never happen. At the lowest altitudes, this would be a parachute system, although, at the higher altitudes, considerably more would be required.

Needless to say, once such a system were built on earth, it would presumably be considerably easier to replicate smaller versions on the moon and on Mars, both of which have smaller gravitational fields. Furthermore, it is likely that the threat from terrorists could be largely mitigated on the moon and on Mars due to careful screening of all individuals prior to their launch from earth. When considered with advanced engines such as Hall effect engines, and ion engines, a total transportation scheme could be put in place that could largely obviate the need for chemical rockets for slow solar system travel among the inner planets. On the other hand, equatorial GEO orbits are a poor choice for escape velocity departures from planets and from the moon, and large plane changes for the orbit would be required. When coupled with long travel times, exceeding 24 hours traveling up or down the SE, and even longer, multi-month times required to shift orbits using ion engines followed by multi-year times to accelerate slowly to other planets; compared simply to using more direct and shorter duration travel times using old-fashioned chemical rocket vehicles it could be economically prohibitive to travel to

nearby planets using an SE. The geo-political issues must not be overlooked, either. At relatively few times in the history of earth has it been possible for any government to maintain a fixed focus on a single task for periods of 20 years or longer, as likely would be required for designing, fabricating, and building an SE.

More importantly, for the purposes of considering SEs for use on Spaceports and Ranges of the future, there are four major factors that must now be considered:

- Carbon nanotubes are only now being fabricated in small quantities in laboratories. Whether their manufacture, or the manufacture of similar performing material, can be extended into multiple tons remains to be seen.
- None of the present-day United States lies exactly on the Equator, with nearby access available for existing public transportation. An SE would be outside the continental United States, requiring a massive investment in building infrastructures to support the SE in what would presumably be a rather remote part of the world.
- The lengthy development and fabrication timeframe implies that construction of an SE would not occur within the timeframe identified as germane to this report, if indeed by even the latter twenty-five years of the 21st Century. The technological breakthroughs required are still simply too distant for serious consideration at this time.
- The political and legal wrangling implicit in undertaking such a massive project (that could fall most anywhere on earth in the event of a catastrophic failure) would require major shifts in governmental policies throughout the world. Obtaining the necessary legal approvals and treaty agreements required in advance to building such a system are certainly not likely in the next thirty years.

For these reasons, in spite of the obvious cost savings likely to be achieved in terms of \$/lb to GEO orbit, it is not likely that SEs will impact continental US Spaceports and Ranges through the 2030 timeframe. SEs need not be seriously considered at this time.

6.0 FUTURE RANGE ARCHITECTURES

There have been numerous reports, papers and presentations attempting to predict both the future of the space industry and the future architectures of spaceports and ranges. The Advanced Range Technology Working Group (ARTWG)²⁷⁴ and its counterpart, the Advanced Spaceport Technology Working Group (ASTWG),²⁷⁵ were created to establish these future architectures and to formulate the road maps to success.

Since the future is by definition infinitely long -- existing from now to infinity -- it is necessary to specify what parts of the future are under consideration. Through coordination with numerous other efforts, ARTWG has chosen the following periods:

- Immediate: Present to 2009
- Mid Term: 2010 to 2015
- Far Term: 2016 to 2028

In reviewing available technical papers and articles on proposed space programs, space vehicles, military space needs and other space users; common range needs and characteristics begin to emerge. When these characteristics are integrated with our present knowledge of range history and general industry development patterns; and assuming that one size does not fit all, it is possible to predict that ranges might easily evolve along the following categories:

- Modified Existing Ranges
- Test & Evaluation Ranges
- Commercial Ranges
- Military Ranges
- Advanced Ranges

The above predictions are made based on the evolution of existing technologies, space vehicle design and fuel sources. Obviously somewhere along this timeline, one must consider the possibility of disruptive technologies being introduced. These technologies, by their very definition, are unpredictable and can redirect, or make obsolete, an entire industry.

6.1 MODIFIED EXISTING RANGES

Although there are varying opinions on how the range of the future may function and on how to draw an accompanying roadmap, it is obvious where the roadmap starts. The starting point must be the present ranges and their current architecture. The present space industry -- with its vehicle manufacturers, satellite manufacturers, range designers and range operators -- is organized and designed to work within the constraints of the

²⁷⁴ <http://artwg.ksc.nasa.gov>

²⁷⁵ <http://astwg.ksc.nasa.gov>

existing ranges. In today's economy, it is unlikely that a business plan case study can be made that would totally ignore or scrap the infrastructure, assets, experience base, and investments already in place at the Eastern Range and Western Range. Therefore, it is easy to predict that in the near future, range architecture will evolve from the existing architecture of the Eastern Range and Western Range. Even the smaller ranges (Kodiak, Wallops, PMRF, Sea Launch, etc.) presently use similar architectures.

Starting with the existing ranges, the general architecture out to year 2009 can be predicted based on current, in place, modernization programs. Both major ranges are the property of the U.S. Air Force. The Air Force has a Range Standardization and Automation program (RSA-II) currently in place. This program covers modernization and standardization of both the Eastern and Western Ranges out until about 2009.

Lockheed-Martin is the RSA-II contractor. The RSA-II program supports the Spacelift Range System (SLRS) by providing architecture & integration, standard & automated open hardware and software, range safety, range operations, weather, planning & scheduling, digital Comm (ATM), Mobile CMD & TLM, Optics, and GPS for Metrics²⁷⁶.

A major goal of the Air Force is to lower the cost of operating the ranges. Some of the plans to achieve this goal are as follows²⁷⁷:

- Standardize both the Eastern and Western ranges
- Automate resources to minimize the “standing army”
- Eliminate or significantly lower downrange (Antigua & Ascension) operating costs
- Eliminate un-necessary range radars
- Switch to a GPS-based tracking system
- Switch to a space-based tracking and command destruct system

In summary, near-term ranges will probably be evolved versions of the existing ranges with significant modifications to control costs. Ranges will probably look much like the RSA-II blueprint. New technologies, that quickly mature, may be implemented and result in changes to the existing blueprint. For example, the use of mobile, unmanned assets may start to appear during this time period.

6.2 TEST & EVALUATION RANGES

As future spaceports and ranges mature, there will still be a need to test and evaluate (T&E) the early prototypes and unperfected one-of-a-kind space vehicles. T&E ranges will be required for both Expendable Launch Vehicles (ELV) and Reusable Launch Vehicles (RLV).

²⁷⁶ <http://lmso.houston.external.lmco.com/es/rsa/>

²⁷⁷ “Transition to a Space Based Range”, Space Congress 2002, Lt Col M. Coolidge, Patrick, AFB

The laws of physics, when applied to hardware with known efficiencies, dictate the minimum amount of energy required to lift any particular mass from the earth's surface to orbit. These chemical energies are significantly higher than what is publicly acceptable today in large modern commercial aircraft (even SSTs). When stored in thin wall tanks adjacent to large quantities of onboard oxidizers, the task of protecting the public and spaceport workers becomes very difficult unless significant geographic safety zone buffers are selected.

Even if the launch (or takeoff) is successful, a public hazard still exists since the chemical energy is not being consumed but only converted into kinetic energy (vehicle velocity) and potential energy (vehicle altitude). Both of these can quickly combine to pose a significant threat to humans and property. The problem is now aggravated by the speed, accuracy, and consequences of abort decisions. Protection may eventually come from increasing reliability of launch hardware, but until such time, physical protection through safety zone buffers will remain necessary.

Multi-stage ELVs that drop off heavy components within the earth's atmosphere will require even more protected space to assure these components do not fall on people or property. Oceanfront spaceports could remain optimal for space vehicle test and evaluation missions, long after inland spaceports become the norm for spaceports.

6.3 COMMERCIAL RANGES

Many States are investing now so that they will be in a position to capitalize on Commercial Spaceport and Ranges when they become technically and economically feasible. One of the keys to commercializing inland spaceports and ranges is a family of economical RLVs with safety and reliability characteristics similar to today's commercial airliners. Other key factors include:

- Customer base willing to support an expanded launch capability
- Trained workforce
- Available insurance
- Solutions to environmental concerns

NASA, the US Military, and X-prize²⁷⁸ contestants are all working to solve the reliable and economical RLV problem. They all recognize the potential launch cost savings that can materialize with the development of an economical RLV. These vehicles will also simplify the task of designing spaceports and ranges for commercial applications.

Being able to reuse a significant portion of a space vehicle will help in lowering the overall \$/lb cost-to-orbit. The Space Shuttle is an example. The Space Shuttle is a

²⁷⁸ <http://www.xprize.org/>

hybrid RLV, not a true RLV. The External Tank (ET) is not recovered and the Solid Rockets Boosters (SRBs), although recovered, require expensive remanufacturing and must be returned to the factory for refueling. Although with the current Shuttle design it is not feasible to recover and reuse the ET, if it were possible to recover, refuel, and quickly reuse these fuel-storage components, significant hardware costs and man-hours would be saved and a lower cost-to-launch would be achieved.

The future spaceport and range architecture for a family of RLVs will no doubt be highly dependent on the RLV configuration. RLVs that include a vertical takeoff or vertical landing segment in the operational profile will probably require larger buffer zones than those that operate in a pure the horizontal configuration. With the horizontal configuration, lift is provided by aerodynamic forces that continue, even with an engine out, as long as forward motion remains. This configuration should be inherently safer than a vertical takeoff or landing configuration that is relying totally on engine thrust for lift. Spaceports for horizontal configuration RLVs will probably have many of the characteristics of existing airports.

So far we have only discussed RLVs. Commercial spaceports and Ranges could also service reliable single-stage-to-orbit ELVs that, after delivering the payload, can dispose of all their hardware in space or can assure its complete disintegration during re-entry. Operationally, such a single-stage ELV would be similar to a RLV that never returns for landing.

6.4 MILITARY RANGES

Future military plans suggest that space and access to space will be key strategic elements of any military plan and its execution. The Air Force Space Command's *Strategic Master Plan for FY02 and Beyond*²⁷⁹ talks in terms of:

- Globally integrated aerospace force
- Air and space superiority
- Dominating the space dimension of military operations
- Protecting against air and space threats
- Space forces and the information they provide are a preeminent force multiplier
- Space control
- On-demand space transportation and space asset operations
- Our ability to control space will be crucial
- Mission Support capabilities to support a fully integrated Aerospace forces

²⁷⁹ <http://www.spacecom.af.mil/hqafspc/library/AFSPCPAOffice/2000smp.html>

These topics clearly drive home the significance of space in future military operations and indicate the military's plans to control space, and, through this control, to:

- Enhance their ability for controlling space in the 'kill cycle'
- Dominate more completely against any terrestrial threats in terms of
 - Enhanced reconnaissance
 - Delivery of precision guided munitions
 - Post-strike target damage assessments

Other open literature documents describe the configuration and missions of future military spaceplanes:

- TAV (Transatmospheric Vehicles)²⁸⁰
- MSP (Military Spaceplane)²⁸¹
- X-40²⁸²

From these perspectives, it is obvious that the military will continue, well into the future, to require their own spaceports and accompanying ranges. Successful military missions require that the following activities be carried out in a secure and often secret environment:

- Mission planning
- Mission briefing
- Deploying and staging of assets and resource, including space vehicles
- Outfitting, arming and configuring both manned and robotic space vehicles
- Outfitting and integrating intelligence gathering payloads with space vehicles
- Preparing for launch
- Establishing launch times, inclinations and directions
- Mission debriefing
- Mission turn around

Accomplishing the above activities within the constraints of a commercial or joint-use spaceport and range would be difficult and probably would result in unacceptable mission compromises.

So, if the military continues to have their own spaceports and range facilities well into the future, what will be their architecture? Probably, these facilities will remain very similar to state-of-the-art commercial spaceports and ranges at that time; except with additional infrastructure to carry out and protect their unique assets and to accomplish their classified requirements. If heavy-lift ELVs are being used for some portions of the mission (e.g., launching intelligence gathering satellites), then an oceanfront or

²⁸⁰ <http://www.airpower.maxwell.af.mil/airchronicles/apj/spacast3.html>

²⁸¹ <http://www.fas.org/spp/military/program/launch/msp.htm>

²⁸² <http://www.dfrc.nasa.gov/History/x-planes.html>

uninhabited buffer zone will still be of significant importance. Military spaceplanes that have perfected horizontal takeoff and horizontal landing could operate from spaceports that look very much like today’s airbases. Isolation of the spaceport/base from the public will still be an asset due to the following:

- Loss of the intelligence value of
 - Preparation activities
 - Vehicle types and configuration
 - Launch times and directions
- Energy hazards
- Noise and other environmental considerations

6.5 ADVANCED RANGES

Advanced Range (and Spaceport) architectures will be heavily dependent on the types of advanced launch vehicles being utilized by the commercial and military sectors. As reliability increases and operating profiles are perfected, the buffer zone requirements should decrease and the human and cargo loads should increase significantly.

To summarize what the future likely holds for spaceports and ranges, it is best to look at the numerous plans that others have prepared. Descriptions and insight into future range architectures are available from the following:

- **KSC/CCAS 50 Yr Master Plan**²⁸³ – 8/02 - Interagency collaboration between: U.S. Air Force, Florida Space Authority, and NASA, as well as our other Cape partners—the U.S. Fish and Wildlife Service, the National Park Service, and the U.S. Navy. (Figure 6-1)
- **Cape Canaveral Spaceport Master Plan**²⁸⁴ – 7/02 – Detailed Cape plan with 690 pages; part of 50 Yr Master Plan above
- **Projected Mission Support Functions For Next-Generation Spacelift and Test Range Architectures**²⁸⁵ - 2/02 – Booz, Allen & Hamilton
- **Strategic Master Plan for Fy02 And Beyond**, 2/00, Air Force Space Command²⁸⁶
- **Future Management and Use of the U.S. Space Launch Bases and Ranges**²⁸⁷ - 2/00 – Interagency Working Group

²⁸³ <http://spaceport.ksc.nasa.gov/offices/nasaafmgmt/masterplan.cfm>

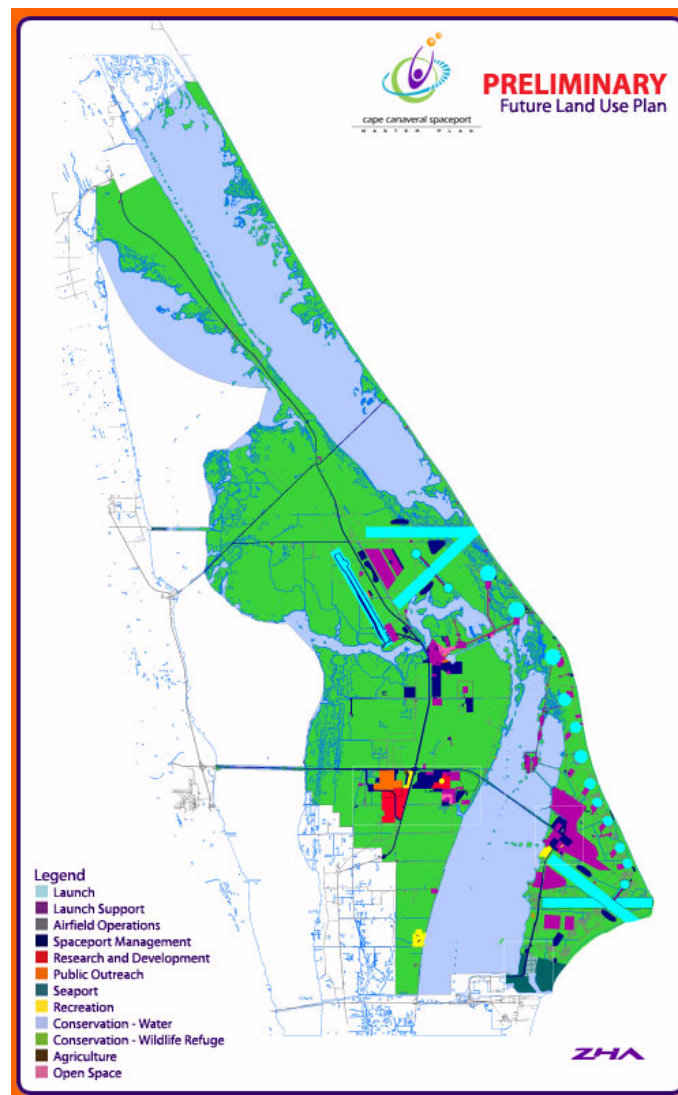
²⁸⁴ <http://spaceport.ksc.nasa.gov/documents/CapeCanaveralSpaceportMasterPlan2002.pdf>

²⁸⁵ “Projected Mission Support Functions For Next-Generation Spacelift and Test Range Architectures”, Booz, Allen, Hamilton, Feb 2002

²⁸⁶ <http://www.spacecom.af.mil/hqafspc/library/AFSPCPAOffice/2000smp.html>

- **Joint Advanced Distribution Simulation (JADS) - Prototype Virtual Range**²⁸⁸
- The JADS PVR project is improving the interoperability and interconnectivity among test centers, ranges, and facilities by establishing communications between various test facilities involved in the JADS Joint Test and Evaluation (JT&E).
- **ARTWG web site**²⁸⁹
- **ASTWG web site**²⁹⁰

As the advanced ranges approach the far term (2016 to 2028), non-traditional launch concepts such as the rail gun or space elevator could start to appear.



²⁸⁷ “Future Management and Use of the U.S. Space Launch Bases and Ranges”, Interagency Working group, Feb 2000

²⁸⁸ <http://www.acq.osd.mil/te/programs/cteip/af.html#1>

²⁸⁹ <http://artwg.ksc.nasa.gov>

²⁹⁰ <http://astwg.ksc.nasa.gov>

Figure 6-1 Future Land Use For KSC & CCAS

7.0 EMERGING COMMUNICATION / DATA NETWORKS TECH.

7.1 ETHERNET OVER SONET (EOS)

The recent trend, at least since 1998 in SONET (Synchronous Optical Network) systems, has been to use framer/mapper chips to concatenate lower data rate bit streams. For example, OC-12 (622 Mb/s) streams have commonly been aggregated four at a time to form OC-48 streams, or sixteen at a time to form OC-192 streams. Similarly, there have been approaches for generating aggregate OC-768 (Optical Carrier 768, i.e., 40 Gb/s) streams either from four-each OC-192 streams, or, from sixteen-each OC-48 streams, depending on particular vendor implementations.

The major problem with this framer/mapper concatenation product upgrade approach using incompatible interfaces has been the ‘forklift upgrades’ that are required.²⁹¹ In other words, entire racks of equipment must be written off, and scrapped, to implement upgrades based on shifting framer/mapper boundary technologies, and this approach is a severe financial burden when implementing upgrades for companies using existing equipment. Additionally, the market preference is to provision OC-48 SONET pipes in units of OC-1/STS-1 (51.84 Mb/s) or OC-3/STS-3 (155.52 Mb/s), instead of wastefully provisioning in larger minimal units (chunks) of bandwidth. Together, these issues have forced many companies to rethink their optimal approach to aggregating data. The economic and technological pressure for generating new revenue streams, through more efficient techniques for provisioning and upgrading services, is now forcing upgrade techniques to be based on reuse rather than on the complete substitution of racks of equipment. Reuse-based upgrades are simply more efficient, less costly, and less disruptive to install.

The answer to being more efficient, thereby avoiding ‘forklift upgrades’, is Ethernet over SONET (EoS), sent using equipment already designed around fixed industry standards, and fielded. Together, chip and equipment developers are now supporting the transport of EoS in the metro sector.²⁹² At least two different approaches exist for implementing EoS: Virtual Concatenation techniques and Generic Framing Procedure.

A Virtual Concatenation (VC) spec by the ITU (International Telecommunication Union) is guiding designers to work in unison to provide hardware that provisions support for various data streams for reusing already fielded non-framer/mapper hardware.²⁹³ The result is a non-disruptive, evolutionary approach for transporting data using existing protocols and, more importantly from a user’s viewpoint, existing infrastructure

²⁹¹ Keenan, Robert. *E’net-over-Sonet gaining in metro*. Electronic Engineering Times, pp. 2, 10, June 10, 2002.

²⁹² Keenan, Robert. *E’net-over-Sonet gaining in metro*. Electronic Engineering Times, pp. 2, 10, June 10, 2002.

²⁹³ ITU-T G.707 2000

hardware. Further, since the majority of traffic today in a metro space is generated from a PC connected to the network with either 100BaseT or Gigabit Ethernet anyway, efficiencies result from not having to re-format data from Ethernet to another format. EoS therefore provides a method of right-sizing the payload to match customers' preferences for a given yet non-fixed data rate, based on hardware that is already fielded. In terms of a technical overview of what is occurring, a SONET Virtual Concatenation payload is nothing more than a set of byte lanes, for which the individual bytes are carried in separate channels. An input data stream is sequentially mapped, on a byte-by-byte basis, into separate channels, called lanes. Each of the channels that comprise the VC payload is then independently transported over an existing SONET network set of hardware; usually with overhead for including error correction coding, which pushes up the total bit rate of the composite signals as transported.²⁹⁴ The difficulty comes when realigning the channels containing bytes back into a contiguous SONET VC payload, as caused by differences in latency of arrival between the fastest and the slowest channels, and for accommodating statistically varying error correction coding operations. The only way to put the pieces back together again is to buffer all the data with lower latencies and fewer errors until the slowest-arriving and most error-prone channel is available, before reassembling the entire SONET VC payload so that data can be extracted.

The alternative approach to SONET VC techniques is Generic Framing Procedure (GFP), which is likewise governed by an ITU spec.²⁹⁵ Like VC, GFP can better size a SONET payload. However, GFP data packets further carry an 8-byte header to indicate the start, type, and length of the data frame. GFP further supports the use of an extended header to provide increased flexibility for future addressing and multiplexing functions, perhaps for implementing a yet-to-be defined GMPLS. To date, VC techniques seem to be winning over GFP in terms of providing the maximum flexibility and freedom over proprietary framing/mapping techniques specific to a single vendor.

No doubt, some devices will support both VC and GFP technologies if a true market need arises. These devices could sit within an ADM (Add/Drop Multiplexer) or within a cross-connect switch. Such mixed technology devices may provide the ultimate in flexibility, thereby avoiding the costly 'forklift' upgrade.

Still, at least one remaining 'forklift upgrade' will still likely occur, in transitioning from legacy OC-192 SONET physical layer gear to newer physical layer gear, built and sold in compliance with the new 10 Gb/s Ethernet standard 802.3ae dated June 2002. Since both LAN and WAN physical interfaces are defined in 802.3ae, this standard establishes a

²⁹⁴ The generic technique is called FEC (Forward Error Correction). Higher performance systems now sport what is termed Super-FEC, which increases the performance during some types of errors. The exact data rates used are proprietary to each vendor, with some going to 12.7 Gb/s or higher, and some only using 10.7 Gb/s. At least four different data rates are in common use today, but all provide for a common operation for 10 Gb/s Ethernet through put at the input and the output of the entire system.

²⁹⁵ ITU-T G.7041

framework for successfully expanding Ethernet from just the LAN into the MAN and the WAN.

Within the LAN category, 802.3ae establishes short, long, and extended reach capabilities at all three wavelengths in widespread use today: i.e., 850, 1310, and 1550 nm. With these three reaches, operation at short distances up to 990 feet through operation at extended reaches of more than 24 miles are now possible.

Within the WAN PHY (Wide Area Network physical layer) definition of 802.3ae, there are now definitions for physical interfaces operating at a serial data rate of 9953.28 Mb/s, thereby providing full compatibility with OC-192 10 Gb/s SONET operation, in support of VC technologies. (For a more detailed Ethernet-centered view of 802.3ae, please refer back to section 5.1.2.) For now, though, Virtual Concatenation technologies appear to have the edge in transporting Ethernet over SONET using new-to-the-market 802.3ae equipments built in accordance with new 10 Gb/s XENPAK-compliant Ethernet designs.²⁹⁶ These are all based on XAUI interface designs, provisioned with four each 3.125 Gb/s channels called lanes. Running at a raw data rate of 12.5 Gb/s, including error correction coding and overhead, a full 10 Gb/s of Ethernet throughput is provided.

7.2 ETHERNET OVER ULTRA-WIDEBAND (UWB)

7.2.1 Background

As discussed previously regarding Ethernet over SONET (EoS), the recent trend has been to use framer/mapper chips to concatenate a number of lower data rate bit streams, using Virtual Concatenation techniques. Reviewing this concept but briefly, a SONET Virtual Concatenation payload is nothing more than a set of byte lanes, for which the individual bytes are carried in separate channels. Each of the channels that comprise the VC payload is independently transported over an existing SONET network set of hardware. The only way to put all the pieces back together again is to buffer all the data lanes with lower latencies and fewer errors until the slowest-arriving and most error-prone data lane becomes available, before reassembling the entire SONET VC payload so that Ethernet data can be extracted. This is not easily implemented, nor can costs be greatly reduced for new installations. The cost-savings for EoS comes *from re-using already-fielded equipment*.

Clearly, this technique allows using presumably already paid for, or at least financed, equipment, to transport Ethernet over SONET. Nevertheless, therein lies the problem. EoS is not efficiently implemented to reduce initial installation costs by an order of magnitude or more, due to the need to re-use a legacy hardware backbone comprised of already fielded, but expensive, equipment. Due to not providing an order of magnitude

²⁹⁶ JDS Uniphase Corporation, Press Release 07 May 2002.

reduction in costs, EoS is not a disruptive technology, in the classic sense of the definition. Instead, EoS is simply a low-cost way to make the best of a bad situation, and avoid replacing one set of expensive equipment for another set of expensive equipment, while providing better provisioning in terms of bandwidth/data rate allocation to users.

UWB technology on the other hand starts with a clean slate, thereby permitting a truly disruptive technology effect to occur. It is possible to optimize a UWB system from the ground up, as this equipment is, with only a very few exceptions, not yet fielded. UWB technology inherently offers the performance to achieve extremely wide bandwidths and data rates with low power consumption, unlike any other radio transmission technology. Interference immunity is high, and data compression, although needed in EoS system (for example to fit FEC (Forward Error Correction) techniques into a fixed, limited bandwidth), is not required to fit high data rates into a UWB system.

With the current FCC Part 15 rules for UWB, the transmitted spectrum is limited to 3.1 GHz to 10.6 GHz. This is more than enough bandwidth to transmit several Gb/s of equivalent throughput without resorting to esoteric high bits/Hz efficient modulation schemes. A simple technique would provide adequate performance. The real limitation at present is the low output power permitted by the present Part 15 rules. With the present power limits, ranges of only a few hundred feet will be possible at low data rates up to 100 Mb/s or so, likely dropping to a few dozen feet at Gb/s data rates.

The situation with UWB is likely to change, though, once consumer products start to proliferate, and there becomes collective proof that UWB-based systems do not interfere with existing communication systems. Once the rules change to permit full-power use of UWB systems at power levels of tens to hundreds of Watts of average power output, the goal of achieving seamless, wireless LAN/MAN/WAN data connectivity will become possible. Data rates in the Gb/s over WAN distances will become possible, solving the final problem of wideband connectivity to the home or office without requiring the installation of a costly infrastructure, such as needed for Cable Modems employing DOCSIS and DSL over phone lines. One possible path to accomplishing this goal will be to support the Open Mobile Alliance in an expansion of wireless standards to include UWB technology. (Refer to section 7.5.1, Basic Data Formatting Issues, for more on the Open Mobile Alliance.)

7.2.2 Protocols for Ethernet over UWB

The wireless standards required for establishing UWB radio technology as a transport method for Ethernet will involve creating a new physical layer definition. To better understand this physical layer technology, it is necessary first to understand just how UWB signals are transmitted and received.

UWB signals start with the generation of a narrow pulse of energy, ranging in length from 10 ps to 1000 ps. (Early systems used a common duration of typically around 500

ps.) The basic pulse train, resulting from a series of these constant-phase pulses, avoids the discontinuous steps at the pulse edges that would result in narrow spectral spikes for a collection of non-constant-phase pulses. Instead, with constant-phase pulses, a very broad $(\sin x)/x$ power spectrum results, consisting of a single large power peak, with an infinite number of smaller peaks occurring both lower and higher in frequency. The primary energy signature, though, is for a single rounded power peak versus frequency.

To disperse this single large peak further, PPM (Pulse Position Modulation, i.e., Time-Domain Modulation) can be applied. This both modulates the output spectrum and simultaneously spreads the transmitted energy over a wide bandwidth. Depending on whether there is a constant data input, though, it is still possible to see a collapse of the output power spectrum to the same $(\sin x)/(x)$ power spectral density signature as seen when unmodulated. Likewise, it is possible to generate a different, but fixed, signature spectrum for a fixed modulation tone. Neither condition provides a Low Probability of Intercept (LPI).

The solution to this spectral collapse, in the event of non-varying modulation, is to modulate the PPM modulation signal with a PN (pseudo-random) signal prior to modulating the pulse train. The PN signal further provides a selectable security function, whereby squaring loops, typically used for the detection of unknown modulation signals in conventional intercept receivers, are largely rendered useless. With a PN overlay to the PPM signal, the ratio of communication range versus detectability range (which is typically a key figure of merit in designing covert LPI communication systems) is greatly improved. Further, even if an interception receiver is operated close enough to detect that a transmission is occurring, within the range in which detection of the signal can be accomplished with a squaring loop, the PN signal provides a further degree of inherent data scrambling, thereby providing additional protection of the information content transmitted.

Transmission of the signal, though, is but the first step to solving the communication problem. It is necessary also to receive the signal before useful information can be passed through a UWB communication system. The detection solution is to use a time-gated correlator, which multiplies the incoming received RF UWB signal with a stored template of the PN code used to modulate the original PPM signal. The output, converted to baseband, is then a replica of the original PPM signal, which can be demodulated using conventional PPM receiver techniques.²⁹⁷

²⁹⁷ Although UWB systems often claim the existence of processing gain, the same as exists for spread spectrum systems, this is not totally true. In a direct-sequence PN spread spectrum system, the spreading PN code spreads the modulation over a wide bandwidth, and the spread spectrum receiver then collapses the spread signal back down to its original bandwidth, simultaneous to spreading out any interfering signal(s). This ratio of spread bandwidth to non-spread bandwidth defines what is called processing gain. This processing gain reduces the power level of interferers in the spread spectrum receiver, providing Anti-Jam (AJ) performance. Processing gains of 30 dB up to 50 dB, or more, are possible with modern spread spectrum systems. A UWB system does provide the analogy of processing gain in terms of spreading a modulating signal, but, unlike in a spread spectrum system, there is no corresponding collapse of the wideband signal in the receiver. There is likewise no equivalent degree of AJ protection due to processing

All of the original UWB systems used PPM modulation only. However, at least one company, XtremeSpectrum of Vienna, VA, is now using BPSK (Binary Phase Shift Keying) to modulate the phase of the signal to be transmitted by zero or one hundred eighty degrees in place of using time position modulation of the pulse train. The advantage of a BPSK system is that it contains a much more controlled $(\sin x)/x$ spectrum that rolls off faster. It theoretically becomes easier to meet the spectral roll-off masks required by the FCC for the output from the UWB transmitter with the use of BPSK modulation. There is also a theoretical 3 dB advantage in sensitivity for Bit Error Rate (BER) for a given input signal level, assuming that coherent detection is used for receiving the BPSK signal. Such a receiver is considerably more complex than a non-coherent detector, however, and is therefore not often feasible.

A bigger disadvantage for BPSK modulation is that many transmitters display a phenomenon whereby the RF power output amplifier goes slightly unstable during the zero phase crossings, especially at cold temperatures where the output power tends to increase anyway. When this occurs, the advantage touted for BPSK, of providing better spectral output cleanliness, is often largely negated. Such anomalous spurious behavior in the RF power amplifier can be very bad, for it results in a decaying steady state pulse at a fixed frequency coming out of the UWB transmitter. This is neither covert, nor is it spread over wide bandwidths. Fortunately, this can be addressed in the design of the RF Power Amplifier, but, as is usually the case, this phenomenon goes un-noticed during the development phase of a BPSK transmitter transmitting what is, in essence, a form of spread spectrum.

Assuming that the PPM method actually provides a less complex design, with better spreading of energy over wide bandwidths, thereby reducing interference to co-existent communication systems, the standards needed for transporting Ethernet over UWB could be simplified into only two parts. The first part, dealing with standard Ethernet frame issues, could be specified much the same as always. The second part, dealing with UWB details and the associated timing issues, additionally defining a short, fixed PN training sequence to acquire the link, followed by transmission of an offset into a longer PN code, such as is used in GPS, for example, would enable establishing whatever degree of security would be required. With this technique for sending Ethernet over UWB, while permitting quick indexing into a longer, secure, PN sequence, a choice of security level versus ease of access would result. Such a technique could eliminate the need for WEP (which is weak anyway), or TKIP (which is still not implemented uniformly among all manufacturers) for Wireless Ethernet.

gain operating against interferers. A UWB system therefore does not benefit from the same degree from its 'processing gain', as time-gated correlators can be overwhelmed with receiving total power levels only 20 dB to 30 dB above a noise floor in a given bandwidth. Now, 20 – 30 dB immunity against jammers is not trivial, but it is vastly different from the much larger 50 – 70 dB seen in many modern spread spectrum systems. In this context, UWB systems do not truly have AJ processing gain directly proportional to the spreading bandwidth as seen in direct sequence PN spread spectrum systems.

The best way to accomplish establishing a standard for sending Ethernet over UWB would be to encourage the development of an industry standard working group, to establish standards and protocols. Such an effort would likely take no more than eighteen months, to reach a consensus among chip suppliers, potential UWB vendors, and leading customers. Although this may sound like a long time, it is not significantly different from the duration of the negotiations that the 10 Gb/s Ethernet standards committee went through to formalize the 802.3ae specification. Such an effort would go a long way toward establishing a commercial product category that does not yet exist; namely, a wideband scheme for achieving much the same data rates as seen in fiber optic cables, without the need for fiber optic cables. Such a scheme would finally solve the missing “To the Home” link seen with today’s fiber optic transmission systems. The Open Mobile Alliance would be one of the most likely candidates to coordinate this standardization, assuming that it were possible to attract their attention to the matter. (Refer to section 7.5.1, Basic Data Formatting Issues, for the Open Mobile Alliance.)

The overarching probability, however, is that UWB is the next likely transport mechanism for a robust Wi-Fi of the near future. As it is likely that a Wi-Fi with the additional features available with UWB will become a fundamental resource analogous to the ac power grid of today in terms of benefiting future Spaceports and Ranges, UWB is one of the three technologies recommended for further exploration during year two of the RISM-related activities.

7.3 WIRELESS ETHERNET

The recent trend in Wireless Ethernet has been to exploit Wireless Ethernet (Wi-Fi) technology in areas for which it was not originally envisioned. This agrees well with the Wi-Fi philosophy espoused by Sky Dayton of Boingo and Earthlink fame, who claims, “Wi-Fi will be built into everything. It’s like trying to imagine all the uses for electricity before it was invented.”²⁹⁸ If the impact of achieving “last mile” Internet connectivity via Wi-Fi technology happens, this visionary’s philosophy may not be far from the truth.

The grandiose vision of the dot.com era fiber-optic technology bubble was predicated largely on an underlying belief that one “could build it, and they (i.e., customers) would come.” However, the fundamental piece of the puzzle that was still missing and had been missing all along was the “final mile” connectivity. A good analogy would have been if, in the 1950’s, the United States had built the Eisenhower Interstate System portion of the National Highway System (Figure 7-1) without on ramps and exit ramps to enable neighborhood access to the new super highway!²⁹⁹ If that scenario had played out, the boon to commerce would have been limited to just large companies, government facilities, and others with deep pockets that paid for their own egress, and the widespread benefit to the public would not have occurred. The benefit to the public of the Eisenhower Interstate System only became possible with the construction of on ramps

²⁹⁸ Brendan I. Koerner. *The Long Road to Internet Nirvana*. Wired (Magazine) 10/2002, p. 111.

²⁹⁹ US Department of Transportation, Federal Highway Administration,

and exit ramps. With Wi-Fi, the promise of all the hype of the late 1990's relative to the dot.com vision could just happen after all, for Wi-Fi enables on ramps and exit ramps to the Internet.

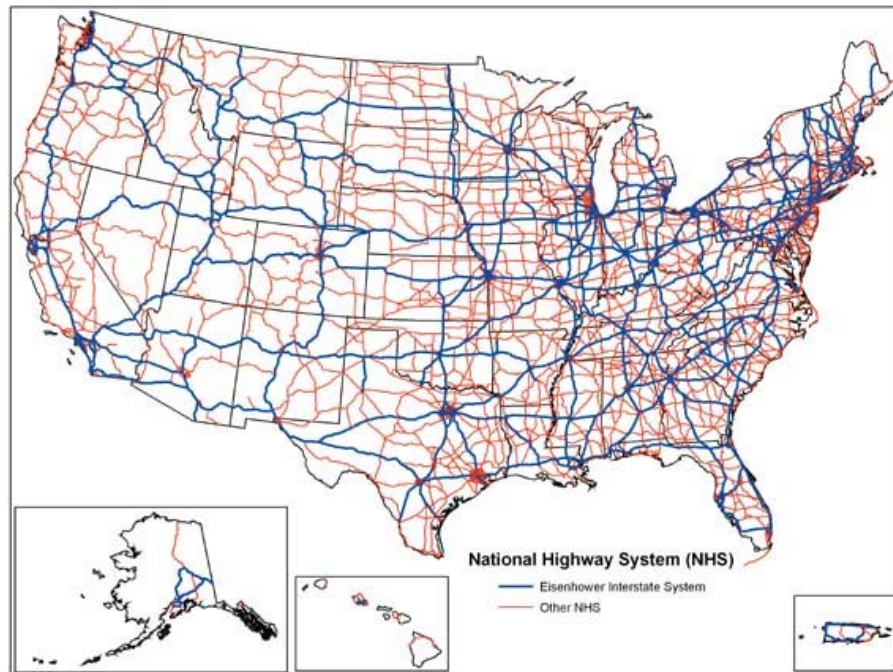


Figure 7-1 National Highway System

In addition to providing egress to the Internet for the “final mile” problem, Wi-Fi also will likely result in a continued loss by Wireless Personal Area Network (WPAN) technologies, such as Bluetooth, of their originally planned and envisioned functionalities and connectivities. Wi-Fi is capturing their market space. In a larger sense, though, this is nothing but the inevitable trend of successful technologies to grow beyond their original purpose(s), and to crowd out less-than-successful technologies. In other words, technical Darwinism acts to establish *de facto* standards at the expense of the also-rans.

As an historical analogy, wired Ethernet, in its early days, was simply a LAN connection technology, competing with numerous other technologies that co-existed at the same time (X.25, Frame, etc.). None of the original founders of wired Ethernet technology in 1972 envisioned the largely wired world of today, mostly interconnected through wired Ethernet, amid a total void of X.25 and other LAN technologies that once coexisted with wired Ethernet. Yet, that is what has happened.

Much the same is becoming true for Wireless Ethernet (Wi-Fi). Wi-Fi is well positioned to solve the “first mile” problem, even though it was originally intended just for use in office LAN environments, to lessen the complexity of interfacing laptops with printers and other such traditional connectivities over bulky infrastructure cables. The functionality of Wi-Fi quickly moved into the WPAN space, as discussed previously in this report, for such additional functions as interfacing to digital projectors and print

servers. Today, it is expanding into the “first mile” and “final mile” domain. In terms of these product spaces, Wi-Fi interface appliances providing WAN, LAN, and WPAN connectivities have become common. All three of these functions are now mostly accomplished through Wi-Fi appliances in many commercial, newly installed, Wi-Fi equipped offices. Zigbee (discussed previously in section 4.2.4), the next WPAN technology, may very well carve out its own niche; but a low-cost, low-performance niche is all that it will likely capture. Barring the introduction of a new disruptive technology that replaces it, Wi-Fi will probably retain the majority of market share in WAN, LAN, and WPAN markets, especially for applications requiring high performance. The overall conclusion derived from watching these trends is that a majority of wireless connectivity for the next decade will likely be accomplished with Wi-Fi, covering the entire set of WPAN, LAN, and WAN market spaces. Eventually, though, an Ultra Wideband (UWB) transport layer may emerge, in place of the ISM spread spectrum technology used today, but it is likely to be but a different underlying transport mechanism for Wireless Ethernet, while still covering the same WPAN, LAN and WAN functions. Wireless Ethernet will likely reign supreme, simply implemented on different bands, across different frequencies (2.4 GHz, 5 GHz, and UWB, i.e., 3.1 GHz through 10.6 GHz).

Reigning supreme in terms of capturing the WPAN, LAN, and WAN markets, Wi-Fi is also enabling the rise of entirely new product paradigms and markets. As an example of this, consider the introduction of voice-activated communication badges, intended to provide real-time, instant communication among hospital workers, technicians, production managers, and other work groups needing portable, instant communication. Resembling functionally the communication badges long ago envisioned on the science fiction TV series of *Star-Trek: The Next Generation*, worn by the crew of the mythical starship Enterprise, the real-world implementation of this same functionality became available in May 2002 through Vocera Communications of Cupertino, CA.³⁰⁰ Vocera’s wireless platform provides hands-free, voice-activated communications throughout any Wi-Fi 802.11b-networked area.

The Vocera Communications System is comprised of two basic building blocks, consisting of Vocera Server Software that resides on a customer server and a Vocera Communications Badge, which operates over a wireless LAN (802.11b interface). In use, one merely taps the communication badge and speaks the name of the individual with whom communication is desired. In return, the Vocera Server Software parses the name of the individual desired and opens a two-way communication link over the 802.11b Wi-Fi to the person addressed.

Before the advent of Wi-Fi, this technology would have made little economic sense, for the spread-spectrum, 11 Mb/s connectivity hardware required would have been prohibitively expensive to embed into such a product unless high production rates, as

³⁰⁰ Vocera Communication press release. *Vocera Communications to Provide Instant Voice Communication over Wireless LAN*. Cupertino, CA. 01 May 2002, <http://www.vocera.com/news/press1.shtm>, retrieved 13 September 2002.

necessary to reduce recurring costs, could be guaranteed *a priori*. A business plan based on such a leap of technology without an underlying infrastructure to support it would have been doomed from the start. For a single product use, this leap would not have been likely. With Wi-Fi gaining widespread acceptance, though, and the delivered numbers of Wireless Access Points (WAPs) now numbering in the millions, the recurring current price of new WAPs permits the successful introduction of new products such as Vocera's voice-activated communication network that stand on the shoulders of the Wi-Fi technological breakthroughs implemented earlier. Assuming an underlying infrastructure of Wi-Fi, the business case for a communicator badge becomes a likely success.

This 'success', though, is not without its perils, for there are other functions that are needed in a communication badge to enable it to become a long-term success. Without adding additional functionality, the voice-activated Wi-Fi market for a communication badge product such as Vocera's current offering would likely not last much longer than 5 years, at the most. The reason is that, looking ahead, there are other features that are needed with a product such as Vocera's communication badge. (In other words, if Vocera does not add these features, the 'half-life' of market acceptance of their product will not last much longer than about 5 years.) First, it would be desirable to reduce the size of these badges, while simultaneously increasing battery life. Second, it would be desirable to add an additional feature of being able to locate instantly where any individual communication badge (individual) was located within a building. The logical way to accomplish all these goals would be to use an Ultra Wideband (UWB) transport link, in place of the 2.4 GHz ISM narrowband spread spectrum. UWB technology eliminates most of the bulky analog RF (Radio Frequency) components needed for conventional radios, such as that used in Wi-Fi apparatus today. With UWB, the bulk of the functionality (~95%) is accomplished in easy-to-miniaturize digital circuitry.

Likewise, with UWB's pulse modulation, peak powers are increased while average powers are decreased. This greatly increases battery life, relative to conventional radio links. The ability to locate the source of UWB transmitters to within inches, based on time arrival information derived at multiple WAPs, could additionally provide geo-location functionality essentially "for free" with an UWB-based communication badge system.

With advantages such as these, and no clear roadblocks in terms of the underlying technologies, it is very likely that within the next decade communication badges largely indistinguishable from those first envisioned on a science fiction TV series could become widely available. If so, they would no doubt become critical for future use around Spaceports and Ranges, as well as even on-orbit. The international space station has grown to the size of a 3-bedroom house over the last year; over the next few years, it will grow to the size whereby communication badges that can instantly locate individuals will no doubt become of great value. The limitation on communication badges with instant location of individuals would likely become more of a privacy issue than a technology issue. Once it became possible to track individuals to within inches continuously, day-to-day, around their work place, it is inevitable that privacy issues would probably normally preclude the continuous monitoring of where individuals were spending their time. At

the least, a management security override, to permit the occasional location of individuals unable to respond, perhaps during an emergency, would be the best way to overcome privacy issues.³⁰¹

The overarching conclusion, however, is that Sky Dayton’s description of Wi-Fi may be most prescient, for it is likely that the communicator badge is but the first of a long line of appliances based on Wi-Fi. Whereas the first uses of electricity were mostly to replace animal-powered prime movers, the uses today would have seemed largely indistinguishable from magic to 19th Century early adopters of electricity.³⁰² It is likely that much the same will happen with Wi-Fi, making it a fundamental resource analogous to the ac power grid of today in terms of benefiting future Spaceports and Ranges.

Because of this fundamental enabling characteristic, and of the perceived importance of Wi-Fi, Wi-Fi is one of the three technologies recommended for further exploration during year two of the RISM-related activities.

7.4 FREE SPACE OPTICS (FSP)

Optical communications systems provide the largest available carrier frequencies. Because of this, they can achieve the fastest data rates possible today, far surpassing the data rates possible with wireless links. The expense of conventional fiber-optic cable-based communication links, at least for commercial users, typically run over \$1 million dollars (US) per mile installed, including the costs of leasing or buying real estate for right-of-way and of equipment. Even when there are no costs associated with obtaining the real estate, installation costs are still significant, as trenches must be dug, and protective conduits or heavily armored cables must be installed. The data rates, though, are very attractive. A much lower-cost alternative to conventional fiber-optic cable-based communications links, providing nearly the same very high and attractive data rates, are Free Space Optical (FSO) communication links. As reiterated throughout this document, the advanced systems on future Spaceports and Ranges will likely need far fewer fibers, cables, and wires to accommodate flexibly linking communication and data networking equipments. In terms of meeting low costs while supporting maximum flexibility with the highest data rates, FSO communications clearly surpass most other communication technologies.

³⁰¹ The hardest problems to solve are often ‘electro-political’ or ‘photon-political’, instead of being simply electrical or photonic in nature. Such personnel-related issues are often the overarching or limiting factors preventing the acceptance of new, advantageous technology.

³⁰² Arthur C. Clarke. *Profiles of the Future: An Inquiry into the Limits of the Possible*. Henry Holt & Company, Inc. 1984. Summarizing, Clarke’s Three Laws of Technology are: 1.) When a scientist states that something is possible, he/she is always certainly right. When he/she states that something is impossible, he/she is very probably wrong. 2.) The only way of discovering the limits of the possible is to venture a little way past them into the impossible. 3.) Any sufficiently advanced technology is indistinguishable from magic.

FSO links are based on infrared lasers and optical detectors. Over short ranges, and often over even greater distances, they are ideally suited for the very highest data rate requirements. They can provide flexible configurations, wide bandwidth, high data rates, small-size, high reliability, and a high degree of safety (compared to RF transmitting links) around pyrotechnics, such as explosive bolts and solid rocket booster segments.

Because of their small-size and medium-power consumption, FSO link equipments provide significant advantages for potential use.³⁰³

- Between buildings
- Launch tower & vehicle (i.e., umbilical usage)
- Interior to Vehicle Assembly Building (VAB) and Orbiter Processing Facility (OPF)
- Micro-network interior to payload-processing facility
- Temporary networks
- Hand-held and wearable transceivers
- Secure links (for security purposes)
- Disaster temporary networks, e.g., hurricane, fire, terrorist event, etc.

Depending on weather conditions, and on the data rates desired, FSO links can extend data networks on the edge of existing wired networks from a few hundred meters upwards to ten kilometers, or farther. The primary consideration that restricts their use is bad weather — thick fog, mainly. Several techniques can be used to overcome weather limitations, including fallback microwave links, which although they can only achieve a few hundreds of Mb/s data rates, they can help establish a limited connectivity through fog where otherwise no high data rate FSO communication link could be supplied. (Of course, during a microburst rain event, microwave systems would likewise experience degraded link-margin, and would thereby provide no backup to an FSO link that would similarly suffer under such a weather event.

Alternatively, an FSO mesh arrangement, whereby multiple FSO links could perhaps route around localized areas with the most severe weather conditions could also provide advantage during micro-cell weather events. Because of the fundamental enabling characteristics of FSO, to provide very high data rates, and of the perceived importance of FSO on future Spaceports and Ranges, FSO is one of the three technologies selected for further exploration during year two of the RISM-related activities.

In preparation of year two activities, and to accommodate learning of the various FSO environmental effects, the Florida Space Institute of the University of Central Florida has entered into a Memorandum of Understanding (MOU) with the subject RISM project of this document, to share test data over the coming year for use in the ECT Project. In

³⁰³Dr. Ronald Phillips, Professor & Director, Florida Space Institute of the University of Central Florida, in private correspondence, suggested most of these applications.

addition, as part of this activity, a sharing of an FSO test range (Figure 7-2), between ISTEf (Figure 7-3) and Launch Complex 46 (Figure 7-4) has further been negotiated.

The Innovative Science and Technology Facility (ISTEF), owned by the Missile Defense Agency, managed by the U.S. Navy Space and Naval Warfare Center, and operated by Computer Science Corporation is located at Kennedy Space Center, next to the 45th Space Wing’s TEL-4 telemetry site. The ISTEf facility is equipped to conduct field research, testing and evaluation on electro-optic systems and new and innovative technologies. The lab is completely fitted with electro-optics equipment and instruments. Under the terms of the MOU, the ECT project will share use of this site with FSI over the coming year.



Figure 7-2
12.4 km

The
FSO

Transmission Path



Figure 7-3 ISTE Electro-Optics Lab at KSC



Figure 7-4 LCX-46 Service Tower

7.5 DATA PROTOCOLS

The formatting of data is critical. Without proper formatting, information simply becomes lost because the right data cannot be found, or, alternatively, the transport of these data can become impossibly difficult. What determines the standards presently used for formatting data? Fundamentally, standards are little more than protocols, which are, in turn, mutually agreed upon methods, procedures, and definitions.

The largest example of protocols, consisting of a layered series of protocols, is the Internet. Internet protocols are documented by what are called RFCs (Requests For Comments). These constitute a collection of more than two thousand documents dating back to the earliest days of the Internet and its predecessor, the ARPANET. Although all Internet protocols are documented in RFCs, not all RFCs are protocols. Some RFCs are simply discussion points, or informational papers. Other RFCs are nothing more than elaborate inside jokes, traditionally published on April Fools' Days. They can be clearly distinguished by their date released in each year (i.e., April 1).

All RFCs are static. Once issued, they are never revised. They therefore form the most complete historical repository of all things Internet-related and protocol-related that exist today governing computer protocols. The methodology followed is to publish a newer RFC that is said to *obsolete* an older RFC. All the RFCs ever published are available on the ftp.isi.edu website. This includes the older, replaced RFCs, which are said to be *obsoleted*. RFCs are typically archived within 24-hours on numerous mirror websites (e.g., <http://www.freesoft.org/CIE/RFC/index.htm>).

In comparison to modern word processor documents, RFCs are primitive documents. They are written as purely text files with primitive graphics made from typewriter characters. Developed in this format during an era of purely text-based computer files, they have not changed. For example, the presently most widely accepted router protocol is IPv4 (Internet Protocol Version 4), governed by RFC1812, dated June 1995, submitted by F. Baker of Cisco Systems. This RFC obsoleted RFC1716, the historical router documentation, as well as the even older RFC1009. All of these RFCs are pure ASCII text documents.

Whereas IPv4 is static, and each RFC is static, the Internet is not. There are also ongoing activities to create IPv6 (Internet Protocol Version 6), to extend the present xxx.xxx.xxx.xxx addresses into even longer addresses, thereby solving the problem of too many Internet users and not enough IP addresses. IPv6, however, is still under discussion, and numerous RFCs presently exist, exploring all the intricate details of extending the ability of the Internet to add more computers. RFC2460 represents one snapshot in time of the evolving IPv6 specification. Likewise, the support of legacy IPv4 networks is also being explored, in RFC3146, dated October 2001, whereby legacy IPv4 hardware is able to continue to operate on the Internet. The Internet evolves. Although the Internet is little more than a series of nested, evolving protocols, not all protocols are directly related to the Internet. For non-Internet protocols, private organizations typically own the protocols, and charge for the distribution of copies, often

as their only way to earn money. Other standards-governing organizations include the IEEE (Institute of Electrical and Electronic Engineers), NIST, the IETF, and the ISO.

The following sections explore the primary protocols envisioned as applicable to RISM (Range Information System Management) related to data formatting: future seamless wireless connectivity protocols, Open System Interconnection (OSI), Routers, MPLS (Multiprotocol Label Switching), and GMPLS (Generalized Multiprotocol Label Switching).

7.5.1 Basic Data Formatting Issues

As discussed previously, the most widespread active example of protocols, actually consisting of a layered series of protocols, is the Internet. At present, it is possible to buy a personal computer, install or attach industry-standard Ethernet cards and/or modems, and simply use a standard set of software applications (Browsers, e-mail, etc.) built around standard protocols and data formats to access services. This assumes, of course, that one selects an ISP (Internet Service Provider) from whom to buy wired Internet connectivity. To date, the user interfaces to the Internet, as well as the Internet itself, have been largely based on just wired and/or fibered technologies within a framework of closely standardized protocols.

The same ease of integration is not true for users wishing to take advantage of wireless connection availability. For example, it is still difficult to integrate services from wireless Internet service providers that are just beginning to supply Internet access and content availability in rural geographic test areas.³⁰⁴ The difficulty is that these prototype services are still based on proprietary interface protocols. Depending on the ‘hiptop’ or laptop wireless device one chooses and uses, whether a cell phone, two-way or one-way pager, a Wi-Fi equipped laptop, a PDA, or other wireless device, each wireless device remains limited to a particular carrier in terms of hardware requirements, standards, and, more importantly, data formatting. To use different wireless devices, a user must buy multiple, different, contracted services, typically based on proprietary protocols, to achieve any semblance of connectivity. This is in marked contrast to both existing 2G and planned 3G cellular voice networks, which have focused extraordinary amounts of effort to achieve a seamless wireless experience for users. Unfortunately, even planned 3G networks have been architecturally planned by committee members who are typically cell phone company representatives. These planned 3G networks have further been envisioned *without* containing the high bandwidth support or flexibility necessary for providing significant Internet access, wireless data access, and future

³⁰⁴ Rural Minnesota and Iowa both have Wireless Internet Service Providers (WISPs) that have set up shop. Xtratyme Technologies, Inc., for example, has built a system with over seventy towers to provide wireless broadband services. Minnesota and Iowa are likely five years ahead in terms of wireless connectivity relative to the rest of the United States. See: Shaw, Russell, *More Web Users Look to WISP*. Investor’s Business Daily, June 24, 2002, p. A6.

growth. This is not caused by a lack of vision on the part of the members of the 3G specification committees; rather, the technologies are simply moving too fast for bureaucratic organizations to respond to in a timely fashion. The unfortunate result is that at present, there are *no* cross-platform protocols that enable wireless data network users to enjoy the same ease-of-use as wireline users currently enjoy and have enjoyed for several years. Clearly, this situation must change before seamless wireless connectivity for mobile users becomes possible at future Spaceports and Ranges.

Fortunately, the groundwork is being built for achieving a seamless connection vision. To achieve seamless, widespread ease-of-access of wireless data, the major issues to be overcome are the:

- Elimination of limited geographic coverage,
- Improved connection reliability and security,

And, most importantly, the

- **Establishment of open-standard protocols to enable data transfer.**

With hardware technologies already demonstrated, and early prototype wireless systems in use today in rural areas, the issue fundamentally becomes more one of establishing protocols rather than one of creating new hardware technologies. Individual proprietary-protocol services have largely explored the early hardware issues and have proven the underlying technology both exists and works. What has been missing is an overarching vision which can be used to tie together all the multiple services available for a typical user; thus providing a seamless user experience; whether on foot, while driving or commuting, or while at a fixed location, to wirelessly access and interact with various types of data.

Within this vision, there must also be technical performance requirements and specifications identified, such as for low latency. Since the transactions are typically very small for most wireless and mobile user applications, latency becomes a major issue because users perceive latency directly while waiting for responses. Raw data throughput is less an issue than latency.³⁰⁵ The vision for seamless wireless interconnectivity must therefore also include low latency for transporting data.

The recognition of the need to remove the existing barriers and permit the global seamless application interoperability for mobile wireless users with low latency is now being addressed through a newly created organization known as the Open Mobile

³⁰⁵ This is the reasoning used to keep data rates low in 3G Wireless systems as originally envisioned by the 3G Wireless specification communities. On the other hand, as applications grow, it will become more important for both latency *and* throughput to be managed for systems serving mobile wireless users to avoid creating user frustration. Likewise, competing wireless systems that provide higher throughput *and* low-latency will provide higher user satisfaction than 3G Wireless systems.

Alliance (OMA).³⁰⁶ OMA was announced on June 12, 2002, and is comprised of over two hundred founding companies representing the world's leading mobile operators, credit card companies, entertainment companies, and brokerage and financial companies, all of whom have a vested interest in supporting the standardization of wireless connectivity for their customers. Included in this alliance are such leading world companies as Alcatel, AOL, AT&T Wireless, BEA Systems, Charles Schwab, China Mobile, Cingular Wireless, Credit Suisse e-Business, Compaq Computer, Deutsche, Ericsson, ETRI, Glenayre Electronics, Hewlett-Packard, IBM, Infineon Technologies, Intel, IBM, MasterCard International, Microsoft, Motorola, Nextel Communications, Nissan Motor Company, Nokia, Novell, Oracle, Panasonic, Qualcomm, Research in Motion, Sony, Sun, Telekom Mobilnet, Verizon, VeriSign, Visa International, Walt Disney Company, and Yamaha Corporation.

OMA was created through consolidating the multiple efforts of the:

- Open Mobile Architecture Initiative, created in November 2002 by Nokia to create common standards for GSM/General Packet Radio Service (GPRS) and emerging 3G wireless networks, with founding membership companies comprised of AT&T Wireless, Cingular Wireless, MM02, NTT DoCoMo, Telefonica Moviles, Vodafone, Fujitsu, Matsushita, Mitsubishi Electric, Motorola, NEC, Nokia, Samsung, Sharp, Siemens, Sony Ericsson, Toshiba, and Symbian
- Wireless Application Protocol (WAP) Forum, an open industry-established world standards body for the wireless industry, intended to work across differing wireless network standards, with numerous member companies representing a dominant cross-section of wireless operators, device manufacturers, software companies, and infrastructure companies³⁰⁷
- Location Interoperability Forum (LIF), an open industry-established initiative formed in September 2000 for the purpose of developing and promoting industry common solutions for Location Based Services (LBS), providing recommendations to the mobile community that are both network protocol and positioning technology independent with the goal of addressing interoperability issues and accelerating time to market of location-based services³⁰⁸
- SyncML Initiative, an open standards body sponsored by Ericsson, IBM, Lotus, Matsushita, Motorola, Nokia, Openwave, Starfish Software, and Symbian;

³⁰⁶ Open Mobile Alliance homepage: <http://www.openmobilealliance.org/>

³⁰⁷ <http://www.wapforum.org/>

³⁰⁸ <http://www.locationforum.org/>

intended to enable data mobility through providing mobile data synchronization and connectability standards; supporting Over-the-Air (OTA) administration of devices and applications while simplifying configuration, updates and support³⁰⁹

- MMS Interoperability Group (MMS-IOP), a working group founded by CMG Wireless Data Solutions, Comverse, Ericsson, Logica, Motorola, Nokia, Siemens and Sony Ericsson in February 2002 to promote Multimedia Messaging Service (MMS) with the objective of ensuring a smooth introduction of MMS to the market through seamless end-to-end operability between MMS handsets and servers from different vendors^{310,311}
- Wireless Village, a closed-standards group created by Motorola, Ericsson, and Nokia to promote wireless instant messaging interoperability among their products³¹²

By linking the activities of a number of organizations encompassing nearly all activities underway for standardizing wireless connectivity, the Open Mobile Alliance addresses wireless connectivity issues that fell outside the scope of any one existing organization, as well as streamlining work that was previously duplicated by multiple organizations. More importantly, OMA further includes organizations that were formerly closed-standards bodies, such as Wireless Village. The goal of OMA is to create interoperability over a wide range of wireless networks in order for applications to work as well on the wireless side as they do on the wired and/or fibered computer networking side of the Internet. With the planned interoperability envisioned by OMA, there comes the possibility of mass adoption of low-cost and high-performance wireless voice and data communication.³¹³ The old engineering saying of “*Better, Faster, Cheaper, pick any two*”, with its tacit implication that all three attributes are not simultaneously possible, will likely be proven false once OMA-compatible products are developed and released into the marketplace. Such products may very well be better, faster, *and* cheaper than existing technology approaches.

³⁰⁹ <http://www.syncml.org/>

³¹⁰ Nokia Press Release, February 19, 2002, http://press.nokia.com/PR/200202/849087_5.html, retrieved 26 June 2002.

³¹¹ MMS itself is defined and approved by the Third Generation Partnership Project (3GPP) and the WAP Forum.

³¹² Briody, Dan. *MEN Behaving Badly*. Red Herring, July 2002, pp. 43-45. (“**MEN**”, in this title, refers to Motorola, Ericsson, and Nokia).

³¹³ <http://openmobilealliance.org/OMA-quotesheet.pdf>

It obviously remains to be seen whether OMA can be successful in its lofty goals. Clearly, though, the weight of ‘doing the right thing’ among the ‘major player’ participating companies identified to date bodes well for the outcome.

If OMA is successful, it becomes obvious that we are standing on the brink of witnessing a private industry initiative that will accomplish the wireless interoperability goal of nearly all LAN, MAN, and WAN functions that are needed worldwide at all future Spaceports and Ranges. The need clearly exists for transporting data between clearly defined nodes in a variety of areas within each Spaceport and Range. With the possible exception of Flight Termination System (FTS) functionality, which will likely always require a separate system altogether, and of long-range communications via satellite or long-distance fiber-optic infrastructures, a wireless universe interconnected through OMA-defined standard protocols at each Spaceport and Range can likely meet the majority of future communication needs, augmenting the existing cabled infrastructure.

7.5.2 Open System Interconnection (OSI) Protocols

OSI (Open System Interconnection) defines seven layers of abstraction governing the interconnection of computers in terms of both hardware as well as data, and apply equally well to wirelessly connected systems as to wired systems. The seven OSI hardware layers are defined as:

- Layer 1, Physical, i.e., PHY (Physical);
- Layer 2, Data Link;
- Layer 3, Network;
- Layer 4, Transport;
- Layer 5, Session;
- Layer 6, Presentation, or Syntax;
- Layer 7, Application.

Layer 2 is further divided into the MAC and the Logical Link Control (LLC) layers. Layer 2 encodes and decodes between bits and packets. The MAC sublayer of Layer 2 controls how a computer on the network gains access to the data and permission to transmit them, whereas the LLC layer controls frame synchronization, flow control and error checking. Layer 3 provides switching, routing, security, and packet sequencing. Layer 4 ensures complete data transfer.³¹⁴

Layer 1 is comprised of topics involving both optical and RF characteristics, depending on the type of hardware. To guarantee interconnection criteria are met, Ethernet hardware, intended for 10BaseT, for example, is defined in terms of both electrical and mechanical connector standards. Likewise, for those hardware items with an optical

³¹⁴ http://www.webopedia.com/quick_ref/OSI_Layers.html

interface, Layer 1 details involving operating wavelengths, DWDM (Dense Wavelength Division Multiplexing) frequency spacings, data rates, optical power levels, and optical reflections. High-speed electrical interfaces likewise must have operating frequencies, modulation types, voltage levels, and other items related to the physical devices defined.

Layer 2 and Layer 3 hardware concepts often overlap, especially over time as what was formerly strictly implemented in Layer 2 starts to be re-implemented in Layer 3 to improve network or system performance. Ethernet hardware, as well as MPLS (Multiprotocol Label Switching) and GMPLS (Generalized Multiprotocol Label Switching) protocols (to be discussed later) each involve the same two layers of the OSI model, Layer 2 and Layer 3. Ethernet switches typically were predominately implemented in Layer 2, although in recent years, with the addition of items such as error correction, they have migrated to Layer 3. Ethernet routers, which perform a similar task as Ethernet switches are typically implemented only in Layer 3. Due to the need to keep complexity to what service providers can manage, likewise, among fielded systems, MPLS has to date been implemented in Layer 2, only. Newer MPLS protocols, on the other hand, are being developed in Layer 3, and, to accommodate greatly higher numbers of simultaneous users with needs of guaranteed Quality of Service (QoS), will eventually likely be done solely in Layer 3.

Along with the seven layers of hardware abstraction of OSI, there are similarly seven layers of data abstraction. At the lowest layer, which is the Physical Layer, the abstraction consists of symbols for the encapsulation of data. The hardware that passes signals at Layer 1 performs such functions as reconditioning, as well as extending the networks, while operating on individual data comprised of symbols. Layer 2, in contrast, encapsulates data at a higher level of abstraction, and passes data that consist of frames. Layer 3, the Network Link Layer, addresses transferring data on not only a single data link, but over multiple data links.

The most common Layer 2 Data Link function is probably ARP (Address Resolution Protocol.) ARP converts an IP address into a physical network address. ARP is most often seen on Ethernet networks, but has been implemented on ATM and Token Ring, along with other networks.³¹⁵ Physical network addresses within Ethernet networks are known as Media Access Control (MAC) addresses. MAC addresses are typically static, i.e., fixed, for a given device, such as a DOCSIS cable modem on a high-speed network, and are six bytes in length. For this reason, MAC addresses often figure prominently in tracing specific computer network wrongdoings, as end users cannot easily modify them, they therefore constitute essentially a “cyber fingerprint” for a virtual circuit terminating/commencing within a LAN. When an Ethernet packet arrives at a gateway (to be discussed in the next section, section 7.5.3), the gateway converts the destination IP address into a MAC address, typically through using an ARP cache. If for some reason no MAC address is available for a specific IP address, the gateway proceeds to broadcast an ARP Request on the LAN, and then listens for a response. If the IP address

³¹⁵ The first RFC discussing ARP for Ethernet was RFC826.

is present, the host at that address will then send an ARP Reply to the gateway, the gateway will update its ARP cache, and packet data will commence to flow to the specific IP address. It should be remembered, though, that ARP is a Layer 2 Data Link function.

Some refer to passing data at Layer 3 as internetworking. The most popular Layer 3 protocol is Internet Protocol (IP), which is itself a nested series of protocols. (Reference Section 7.5, Data Protocols) Although the most popular, IP is not the only Layer 3 protocol. There are other Layer 3 protocols, some of which even provide the ability to transport IP. For example, X.25, an early protocol that has mostly been popular only across Europe, contains a Layer 3 protocol capability, which is itself capable of passing Layer 3 IP data.

Perhaps the most common Layer 3 Network function is IPSEC (which is short for Internet Protocol Security). IPSEC is a security framework that operates at the Layer 3 Network Layer by extending the IP packet header with additional protocol numbers. It can provide VPN (Virtual Private Network) functionality to provide security through encrypting any higher layer protocol, such as Layer 4 Transport, and, at the price of configuration complexity, offers the greatest flexibility of all existing TCP/IP cryptography systems.

Layer 1, 2, and 3 predominately involve topics involving the edges of the network. As one migrates into the core of the network, Layer 1, 2, and 3 are still applicable between adjacent nodes, but Layer 4 topics, involving Transport issues, and Layer 4 topics, involving Session issues, start to occupy the majority of one's attention. It is in this layer that network processors and topics such as switch fabric start to be heavily discussed. These layers are predominately more related to software than to hardware for all except system hardware providers. Users of networks typically focus only on the software topics associated with Layer 4 and Layer 5.

At Layer 6 and Layer 7, the topics are almost exclusively software in nature, governing Presentation (Syntax) and Applications. Layer 7 deals solely with Gateway functions. Gateway functions are, by definition, at the edges of Networks. (For more on gateways, see Section 7.5.3.)

Relative to the study of networks for use on the Spaceports and Ranges of the future, the majority of this document is concerned only with Layers 1, 2, and 3, with Layers 4 and higher largely reserved for later study, as the needs of users become more evident.

This approach, of concentrating on Layers 1, 2, and 3, supports a path that historically was followed with the construction of roads, waterways, railroads, and airports, of first defining the fundamental hardware and technology interface issues, and then defining the higher level switching/routing functions. Even higher level system engineering optimization tasks, of achieving optimal routings, or more efficient system performance, are best reserved until the fundamental foundations are in place. Only when the technical

foundations are in place can the construction of more elaborate system structures and abstractions be achieved.

7.5.3 Repeaters, Bridges, Switches, Routers, and Gateways

As discussed previously while describing OSI Protocols, there are seven layers of abstraction describing the interconnection of hardware and data between computers. As interconnections are made at increasingly higher layers of abstraction, the hardware that connects computers at these seven layers varies from the very simple to the more complex. The reward for increasing interconnection complexity and interconnecting at higher layers is to improve the physical width over which a network can be extended and to reduce network congestion. Simpler interconnection methods limit the maximum physical expanse over which a network can be extended and do not permit managing network congestion.

As shown in Figure 7-5, the type of hardware varies for implementing connections between computers, depending on the OSI Layer through which connections are made. By selecting the appropriate Layer for forming connections, through selecting the proper type of hardware, it is possible to tailor a network's extension in different ways, optimizing a network for physical width, congestion, computer density, maximum data rate, number of Media Access Controller (MAC) address, and an assortment of other attributes.

Application	Gateway	Application
Presentation		Presentation
Session		Session
Transport		Transport
Network	Router	Network
Data Link	Bridge/Switch	Data Link
Physical	Repeater	Physical

Figure 7-5 Method for Hardware Connection Depends on OSI Layer

The hardware devices used to connect computers are known variously as repeaters, bridges, switches, routers, and gateways. The primary function, of interconnecting computers, is the same among all these devices. The nuances due to the choice of connection device, and the subsequent network performance limitations, depend heavily on which of these devices are used and vary considerably.

For example, at the lowest level, Layer 1 Physical, the concern is only with symbols. Repeaters, sometimes also known as repeater hubs, operate at Layer 1 and simply receive symbols and recondition the bits before sending copies of the symbols out to interconnect computers. No error checking is done, and no extension of the physical width of the maximum network size is possible through using repeater hubs. This simple interface serves the sole purpose of increasing connection density, i.e., increasing the numbers of permissible computers within a maximum physical network width, while insuring noise margins are maintained.

The reason that repeaters do not extend the maximum physical width of a network, and work only within a rather small radius, is due to a limitation imposed by what is called the Collision Domain. A Collision Domain is the maximum physical envelope that can be permitted to exist between the two farthest separated devices on an Ethernet sharing a common ‘ether’ in order to avoid collisions in transmitted packets from occurring. Each device on an Ethernet listens first, and only transmits if no signal is heard. If two devices are physically separated too far apart, they both can start to transmit at the same time, causing jamming of signals near halfway points between the two devices. The only way to avoid this unintentional jamming is to keep the maximum physical width of the network below an upper bound. For copper-based systems, this maximum network width upper bound equates to a maximum distance of only 205 meters wide at 100 Mb/s (i.e., 100BaseT) for a network.³¹⁶ If the width of a 100BaseT network is more than 205 meters, two devices on a common Ethernet can listen, not hear traffic, and both can start to transmit at the same time, repeatedly, never detecting that collisions are occurring.³¹⁷

In addition to not extending the maximum physical width of a network, repeaters require that network speeds across repeaters remain constant; i.e., data rates on both sides of a repeater hub must be kept the same. If an older, slower, 10BaseT (10 Mb/s) device is to be connected, all devices on the Ethernet must run at 10 Mb/s. If a repeater hub is used, the slowest device on the Ethernet determines the maximum speed of the Ethernet.

Fortunately, it is possible to extend the Collision Domain, and simultaneously operate different parts of an Ethernet at different speeds, by interconnecting computers at higher

³¹⁶ Optical interconnections can have a different maximum network width. Propagation time is related to the square root of the dielectric constant of the medium, and media with different dielectric constants support different speeds of propagation. The propagation speed of electromagnetic waves passing along a copper twisted shielded pair cable is different than through a fiber optic cable, and the Collision Domain is different.

³¹⁷ The same problem can also occur in wireless networks. In the early days of AX.25, otherwise known as packet radio, in the early 1980’s a phenomenon could occur whereby what was known as a hidden transmitter could continuously re-transmit data, attempting to pass data, while never being able to pass any data due to collisions with another transmitter that would start re-transmitting data at the same time, repeating over and over. Such collisions could repeat for literally hours, and occasionally days at a time, in what came to be known as a ‘fatal embrace’. The solution was to randomize the re-transmit time in the digipeaters with an improved algorithm that would not be reset to a common state among all digipeaters on the network if all AX.25 digipeaters (digital repeaters) lost ac power at the same time over a widespread area.

layers of abstraction. Above Layer 1 is Layer 2, the Data Link Layer. This is the layer in which data and error detection bit framing is provided, as well as being the Layer in which ARP (Address Resolution Protocol) operates. (For more on ARP, see Section 7.5.2.) Layer 2 handles the transmission and reception of frames sent over Layer 1. The hardware used to provide Layer 2 connections is known variously as a Bridge, a Switch, or a Switch Hub. The differences in nomenclature are primarily due to historical legacy. Originally, bridges were two-port devices, used only to connect two extended parts of the same LAN. Bridges with multiple ports, above just two ports, are also known as switch hubs, switching hubs or, more commonly, just as switches.

Unlike the repeater hub, a switch hub has to receive and decode Ethernet frames and test for frame integrity, as well as to then reassemble the data and retransmit the same data in a new frame. Each port of a switch operates in what is called promiscuous mode by receiving all frames on each port independent of destination Media Access Control (MAC) address.³¹⁸ The primary advantage of a switch hub over a repeater hub is that error correction, at the frame level, is provided; unlike a repeater hub that blindly repeats whatever it receives, errors and all. Additionally, and even more importantly, a switch hub extends the Collision Domain of an Ethernet by the fact that only error-corrected frames are re-transmitted. Using a switch hub therefore extends the maximum physical network width, because it extends the Collision Domain limit (to beyond 205 meters at 100 Mb/s). Likewise, since a switch hub retransmits data in a new frame, it also becomes possible to operate one port of a switch at 10BaseT (10 Mb/s) and the remainder of the network at a higher speed at 100BaseT (100 Mb/s). Operating different parts of an Ethernet at different speeds reduces the loading on a network by clearing high-speed traffic through what are essentially ‘express lanes’ within a network, rather than imposing a ‘speed limit’ at a low data rate throughout an Ethernet.

Layer 3 is where routers provide an interconnection function among computers. Depending on the IP destination address and on which port on the router an IP destination address is connected, a router transfers received packets only to one destination port. With this method of operation, routers reduce network congestion by not arbitrarily flooding packets to all ports to which they are connected. Each computer on each router port sees only the packet traffic to and from the computers that are likewise on the same, specific router port. With fewer computers on any given port (often just one or two), network congestion is greatly reduced; compared to the alternative situation in which large numbers of hosts sit on a common Ethernet port. Since Ethernet is highly dependent on keeping network-loading low to operate correctly, routers make the largest improvement in performance by going up the OSI layers while making interconnections between computers. For routers with integral switch hubs, computer density is improved, as well; thereby allowing such routers to provide all the benefits of lower-layer interconnection hardware (repeaters, repeater hubs, switches,

³¹⁸ A MAC address is the physical 6-byte address network address for a particular device connected on a LAN. It essentially represents a distinct and unique digital fingerprint of a device that is connected on an Ethernet.

switching hubs, etc.) while additionally reducing network congestion. Cable Modem/DSL Routers likewise provide additional protection for LANs through providing a built-in NAT (Network Address Translation) function. In the typical usage, such devices often act as gateways to protect 24/7-connected LANs connected to the Internet through DOCSIS cable modems or DSL modems.

A gateway is a generic term applied to hardware and/or software used for interconnecting two networks; each of which is comprised of multiple computers. This interconnection can be done at Layer 7, thereby providing support for complete 7-layer OSI protocols; or, depending on the need, at any lower level within the OSI protocol model, even down to Layer 1. For example, it would be possible to interconnect two networks at Layer 1, at the physical symbol layer. Two networks connected at Layer 1, though, could achieve none of the benefits available of interconnecting the two networks at a higher layer, such as management of Collision Domains, management of network congestion, error correction, support for multiple data rates, or any of the other attributes which would likely prove beneficial in an interconnection at a higher layer.

By definition, a gateway exists only at the edge of a network, or, depending on the viewpoint, between linked networks. Because of this location, gateways often are the logical point to place a firewall, to keep undesired users outside of a network. However, a firewall behind the router still makes sense for those systems needing a gateway implemented, say, only up through Layer 3, consisting of a Cable/DSL Router. Intrusions, although rare, can and do occur through Cable/DSL Routers. Internal Cable/DSL Router firewalls typically employ NAT (Network Address Translation) techniques to protect a LAN from most attacks from outside the network. For more complete protection than possible through a NAT firewall, a software firewall on a machine on the output of a Cable/DSL Router makes sense. Likewise, software firewalls make sense if NAT firewalls are not used. NAT firewalls are often not used in some networks because NAT firewalls have an unfortunate side effect of masking the internal structure of a LAN, thereby blocking access to servers on the LAN to the outside world. For LAN systems that do not require external access to internal LAN servers, however, NAT firewalls are an excellent solution by which to start securing the LAN against attacks from outside the LAN. (See also Sections 4.1 through 4.1.4 for more information on NAT firewalls for wired networks, as well as Section 4.2 for more information on Wireless Ethernet networks, which pose a different set of firewall issues.)

In summary,

- Repeaters (and repeater hubs) manage only network density within a limited maximum physical width for a network, and provide no additional error correction, Collision Domain management, or congestion management for a network. Both sides of a repeater must operate at the same data rate (10 Mb/s, or 100 Mb/s).
- Switches (and switch hubs) also manage network density, but additionally provide error correction and Collision Domain management. In that

Switches provide Collision Domain management, switches can extend the physical width of a network. Switches do not manage network congestion. Switches also permit different data rates on different ports, thereby permitting the efficient interconnecting of slow (10 Mb/s) devices with higher speed (100 Mb/s) devices, without slowing down an entire Ethernet.

- Routers manage Collision Domains, reduce network congestion, extend physical network widths through managing Collision Domains, and simultaneously reduce network congestion. Plain routers do not manage network density. Routers with integral switches, in contrast, can also manage network density, in addition to having all the attributes of plain routers. Routers support different data rates on different ports.
- Repeaters operate at Layer 1, switches operate at Layer 2, and routers operate at Layer 3 in the OSI Protocol. Some special purpose switches also operate at Layer 3 (see 7.5.4 MPLS, and 7.5.4.1 GMPLS, for an example of switches with Layer 3 functionality.)

7.5.4 **Multi-protocol Label Switching**

7.5.4.1 **Background**

“MPLS (Multi-protocol Label Switching) is an advanced way of managing Internet traffic by letting carriers merge different types of data traffic over one IP backbone, improving their ability to offer different classes of service.”³¹⁹ ‘Class of service’ refers to groupings of services with similar requirements for quality of service (QoS). For example, low-latency traffic requires express lanes through a network, in contrast to traffic such as e-mail or other none time-sensitive data, which can be delayed, or in some cases, even stored and forwarded, without any noticeable effect on end-users.

MPLS started as a proprietary routing method from Cisco known as Multiprotocol Tag Switching. Today, MPLS is an international standard and is non-vendor specific. (MPLS is also referred to as Multiprotocol Lambda Switching in some futuristic writings.³²⁰) In all cases, MPLS is intended primarily to provide VPN (Virtual Private Network) segregation of traffic for QoS performance reasons while coping with very large numbers of users; at lower cost than competing technologies can provide. This segregation of traffic is sometimes known as ‘flow aggregation’.³²¹ The standard claim

³¹⁹ Smettannikov, Max. *Beware MPLS VPN Tech Challenges*. Interactive Week, p. 14, August 20, 2001.

³²⁰ http://www.lightreading.com/document.asp?doc_id=5487

³²¹ http://www.lightreading.com/document.asp?doc_id=5487

is that MPLS provides businesses with IP (Internet Protocol) VPNs that are thirty percent cheaper to run than if run using ATM (Asynchronous Transfer Mode) or frame relay techniques.³²² With this cost saving advantage, and especially for businesses with significantly large numbers of subscribers, the economic incentive to use MPLS becomes significant for establishing on-demand VPN services with defined QoS requirements.

The Internet Engineering Task Force (IETF) governs the standards for MPLS.³²³ The IETF is a large, open, international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet. The IETF is open to all interested individuals. MPLS draft position papers are available on the IETF website.³²⁴

MPLS achieves its success using Border Gateway Protocol (BGP) for establishing routing tables in large networks. This is done by adding labels to packets to prevent intermediate routers from needing to interrogate individual packets to determine routing. A Label Edge Router (LER) at the edge of the network first adds labels to all packets intended for a common destination, and intermediate Label Switch Routers (LSR) along the Label Switched Path (LSP) then route these packets more quickly by simply examining the labels. A second LER, on the output side of the network, then removes the label. The result is that packets are routed much more quickly with MPLS than from using older IP techniques; thereby providing improved QoS performance for MPLS versus older routing techniques.

As presently implemented, most metro networks provision MPLS in Layer 2 of their network. For example, in August 2001, eight million residents in Hong Kong gained the ability to view movies on their home computers over Ethernet connections in their apartments based on a Layer 2 implementation of MPLS fielded by Hutchison Global Crossing, a joint venture company. With MPLS, it became possible to deploy virtual circuits to millions of users simultaneously in Hong Kong to provide movies-on-demand, with guaranteed quality of service.^{325,326} In spite of the subsequent bankruptcy of joint-partner Global Crossing, this movies-on-demand entertainment service continues in

³²² Smettannikov, Max. *Beware MPLS VPN Tech Challenges*. Interactive Week, p. 14, August 20, 2001.

³²³ <http://www.ietf.org/>

³²⁴ <http://www.ietf.org/ids.by.wg/mpls.html>

³²⁵ Smettannikov, Max. *Beware MPLS VPN Tech Challenges*. Interactive Week, p. 14, August 20, 2001.

³²⁶ Hutchison Global Crossing deployed the Hong Kong MPLS system. With the subsequent demise of the parent, Global Crossing, which is now in Chapter 11 (as of June 2002), it is unclear whether additional such MPLS systems will be forthcoming in the near future. The fact that such technology already has been successfully fielded, however, bodes well for implementing VPNs with MPLS in the future. It is already a proven, although early, technology, for high QoS data paths.

operation today in Hong Kong, and became solely owned by Hutchison Whampoa, Ltd. as of April 30, 2002 in a highly-publicized buyout.³²⁷

Layer 2 is typically a ‘dumb’ layer of OSI (Open System Interconnection), as discussed earlier. The Hong Kong system, although successfully fielded, did not use Layer 3 BGP, or an even higher layer BGP, due to the uncontrollable complexity that that would have been entailed had it been attempted. Layer 3 BGP is not yet fully implemented and is well beyond the capability of service providers to manage for even the parts that are defined. An early Layer 2 approach was adequate for providing the desired QoS and did not outrun the managing capability of the service providers in Hong Kong. Layer 2, unfortunately, provides no way to provide flexible upgrade paths to provision greatly higher numbers of users. Ultimately, Layer 3 support for BGP will be required before greatly larger numbers of users can be allowed to co-exist in co-configured VPNs. Cisco Systems, Juniper Networks, and AT&T all participated in RFC 2547, an Internet Engineering Task Force informational Request for Comment, in the fall of 2001 to address more fully the details of providing VPNs configured at Layer 2. As of January 2002, draft RFC2547 bis-01 replaced RFC 2547 as the present working document, and RFC 2547 continues as a work in progress.³²⁸ In time, Layer 3 BGP will no doubt be fully implemented and will have its documentation fully finalized.

In the meantime, the basic algorithm for Layer 2 BGP is presently of an order of complexity of $O(n)$ instead of $O(n^2)$, which indicates that it is inherently more scaleable than early BGP versions. Although the Hong Kong system is impressive, the installation of the MPLS VPN network in Hong Kong is very likely near the maximum complexity that existing fielded technology can handle in terms of routing virtual circuits (VCs) through VPN (Virtual Private Networks).³²⁹ As the population growth of Hong Kong is heavily constrained by both land mass area and mainland Chinese emigration policies, implementing an early Layer 2 BGP system implementation is probably adequate to provide adequate growth potential for decades to come.

Does this seemingly minor detail, of whether Layer 2 or Layer 3 BGP should be used for a MPLS network, matter for future use in Spaceports and Ranges? Arguably, one could make the case that it does not, in terms of sheer numbers of simultaneous users, at least

³²⁷ “Hutchison Whampoa Ltd said it will buy Asia Global Crossing's stake in their Hong Kong telecoms joint ventures in a US\$120 million deal that provides the ailing seller much-needed cash. Under terms of the deal, the Hong Kong conglomerate controlled by Asia's richest tycoon Li Ka-shing will buy Asia Global Crossing's 50 percent interest in Hutchison Global Crossing, as well as its 42.5 percent interest in ESD Services and its 50 percent interest in Hutchison Globalcenter. The transaction values the businesses at 20 percent of the \$1.2 billion worth assigned when Hutchison Global Crossing was formed in late 1999, underscoring the plunge in global telecoms valuations -- and the seller's thirst for cash.” Reuters – 30 April 2002. http://www.siliconvalley.com/mld/siliconvalley/business/special_packages/3166812.htm

³²⁸ <http://search.ietf.org/internet-drafts/draft-ietf-ppvnpn-rfc2547bis-01.txt>

³²⁹ <http://www.ietf.org/proceedings/00jul/SLIDES/nbvnpn-rfc2547/>

for terrestrial Spaceports. The present population of Hong Kong, at eight million, is likely already larger than all the *terrestrial* Spaceport users for the near and even midrange period out past thirty years, at least. Yet, for a Spaceport in space, say, aboard an International Space Station, the need for implementing MPLS using BGP at Layer 3 is very likely to be required. After all, how many tens of millions of users *might* want to watch an event occurring on orbit, or in space? In the event of a major disaster, there could be considerable interest in establishing a VPN connection to receive guaranteed QoS video. There would likewise be considerable interest, say, for selecting the virtual vantage point of several camera views for viewing the first manned Mars landing, or manned Jupiter moon mission, through an HDTV (High Definition TV) signal passed through an Ethernet connection through an orbiting Spaceport. By providing multiple digital streaming video channels, it would be possible to provide user-selectable options to select which of several camera views by which to view historic events. Although more far-fetched, the first extraterrestrial encounter, as remote a possibility as that might be, would no doubt draw an even larger crowd. All of these events would clearly require supporting significantly higher numbers of users than presently can use the Hong Kong movie-on-demand system.

The need for RFC2547, or equivalent, performance at Layer 3, for supporting tens if not hundreds of millions of users simultaneously through VPNs, with guaranteed QoS requirements, will likely be needed for communicating with Spaceports in space from Earth, in view of the multiple hundreds of millions of potential users desiring concurrent connectivity and selectable signals through digitized HDTV by the year 2028.³³⁰ MPLS VPN technology is clearly a technology that will need continuous monitoring, if not critical and timely investment, as Layer 2 BGP is improved, and as Layer 3 BGP becomes fully implemented, to support increasing the numbers of VPN users that can be simultaneously supported

7.5.4.2 Generalized Multi-protocol Label Switching

Whereas MPLS is primarily a router technology, implemented in electronics, there is yet another MPLS to consider for future Spaceports and Ranges: namely, Generalized Multiprotocol Label Switching (GMPLS).³³¹ GMPLS takes the MPLS function out of the electronics domain and moves it into the optical networking domain. The all-optical

³³⁰ Spaceports, to some, represent a terrestrial-only portal to space. Yet, will not Spaceports likewise represent a portal to deep space, to the Moon, and to Mars, if placed in orbit? A spoke and hub system of travel in space is likely to develop, simply to keep fuel needs manageable, as well as to match the differences between mission-specific deep-space vehicles versus vehicles intended only to launch from Earth into a transfer LEO or MEO. By 2028, a Spaceport in orbit around the Earth, supporting travel to Lunar distances and beyond, is possible, although not likely due to the funding difficulties for the deep space infrastructure it would imply.

³³¹ Some early users referred to GMPLS as **Multiprotocol Lambda Switching**, but obvious confusion with the **Multiprotocol Label Switching** terminology quickly forced the creation of the GMPLS acronym to avoid creating confusion with the MPLS acronym.

network has long been a highly-prized goal, for reasons of eliminating the cost of expensive optical add-drop connections that, to date, have had to convert from optical to electrical, make the add-drop connections, and then convert the remaining electrical signals back to optical before feeding the next optical add-drop box. The OEO (Optical-Electrical-Optical) conversion process is both expensive and prone to reliability problems. GMPLS is a major step in moving from an existing OEO methodology to an all-optical methodology.

GMPLS, as presently implemented, involves the incorporation of tunable laser technology that not only allows provisioning of dynamic assignments of wavelength frequencies remotely for customers on standard ITU grid wavelengths, but also reduces the sparing needs of lasers through generating multiple wavelengths with but a single tunable laser. Each customer therefore becomes attached to the network while exposed to all wavelengths, while being configured to receive on but specific wavelengths, each of which is addressable through transmitting on the properly addressed wavelength at the head of the system. (The exposure to all modulated wavelengths occurs through a common fiber-optic ‘pipe’ connected to all users simultaneously.) GMPLS techniques using different wavelengths specifically tailored to segregate information presently address the metro edge, access, and core applications markets, with fixed, yet selectable, wavelengths, chosen on the ITU grid of possible wavelengths.

The standards for GMPLS are also governed by the Internet Engineering Task Force (IETF), the same as for MPLS. Specific draft papers dealing with present standardization of various aspects of GMPLS are available on the IETF website.³³²

Some of the fastest tuning GMPLS transmitters presently available use vertical cavity surface emitting laser (VCSEL) and micro electro mechanical structure (MEMS) technologies to tune and lock to a specific wavelength in less than 200 microseconds, tuning at a changing wavelength rate of 2 nm per 50 microseconds. With these fast-tuning techniques, partial L-Band or C-Band optical wavelength coverage approaching 10 nm total change in wavelength, or more, has been possible since at least early 2001, at least in prototype lasers. Slower tuning systems, however, are still available using temperature-tuned, Etalon-based, laser cavities and through using modulation of laser injection current.³³³

Whatever the tuning method, a common wave-locker technology is typically used, based on using dual optical filters for each wavelength. Sensors (i.e., photodetectors) are

³³² <http://www.ietf.org/internet-drafts/draft-ietf-mpls-bundle-03.txt> , <http://www.ietf.org/internet-drafts/draft-ietf-mpls-lsp-hierarchy-06.txt> , etc.

³³³ Sanders, Scott T.; Mattison, Daniel W.; Jeffries, Jay B.; Hanson, Ronald K. *Rapid temperature tuning of a 1.4- μ m diode laser with application to high-pressure H₂O absorption spectroscopy*, Optics Letters, vol. 26, No. 20, October 15, 2001, pp. 1568-1570. Online: http://www.engr.wisc.edu/me/faculty/sanders_scott/RTtuning.pdf retrieved 11 June 2002.

placed behind optical filters with high-pass and low-pass structures overlapping at the midpoints between ITU grid wavelengths. Analogous to the mark and space filters used for receiving radio teletype Frequency Shift Keying (FSK) modulation, which discriminate between two wavelengths (two frequencies) to generate automatic threshold corrections for setting automatic decision making thresholds in an electrical FSK frequency demodulator; the optical equivalent today provides a wavelength locking function to stabilize the feedback circuits and fix a tunable laser's output wavelength. With the appropriate combline repetition function designed into the optical filters, the repetition of the filter functions at regularly spaced ITU grid wavelengths is even possible. The major caveat is that the proper external method, to select which of the repeating pass bands is to be selected, must be used. Likewise, tunable lasers must be blanked both on power-up and when tuning, to avoid sweeping across other users' wavelengths, which would cause optical jamming within a fiber optic cable. Aging effects, temperature effects, injection current variations, and other drifts also must be accounted for, as well as blanking; typically by wrapping up to five control loops around typical DFB (distributed feedback) lasers used for telecom applications.³³⁴ Once the proper control loop adjustments are made, however, meeting Telcordia specifications, for providing operation up to twenty years, is possible with existing systems built around tunable lasers.

Unlike DWDM (Dense Wavelength Division Multiplexing), GMPLS routes multiple modulated optical wavelengths to each end-user, instead of only one. In DWDM, an AWG (Arrayed Waveguide Grating), or similar device, typically performs the optical drop demultiplexer function on the receiving end of the optical backbone prior to passing a single data stream to the end-user. In GMPLS, the end user becomes responsible for the optical drop functions. The primary leaders in GMPLS technology at present are Ciena, ONI, Nortel, Movaz, ONI Systems, and Ophos. Market consolidation over the next eighteen months is likely, as companies struggle to survive. Hence, it is likely that within two years, this list of six vendors will be reduced to perhaps only three.

Will GMPLS achieve acceptance in the general marketplace? For the near term, the answer is no. There is no financial incentive driving any need for this technology, and relatively few fielded systems exist relative to the numbers of DWDM systems that are deployed. However, for the span of time extending to 2028, the likelihood is that

³³⁴ Telecom refers to high performance, high-rate, longer-distance products. In contrast, Datacom refers to lower performance, lower-rate, shorter-distance products. There is starting to be some overlap in VCSEL lasers in these two markets. DFB lasers, on the other hand, are solely used for Telecom, typically for externally modulated applications at 10 Gb/s and higher data rates, using Mach-Zehnder external modulators. Mach-Zehnder modulators are, fundamentally, Michelson interferometers, with modulation drive signals applied through broadband interdigitated finger coupling structures. Typical drive signals, for 10 Gb/s Mach-Zehnder external modulators are 7.5 Vdc peak, amplified with power amplifiers having flat passband response, flat to within 1 dB from 35 KHz through at least 13 GHz, and having group delays of less than +/- 10 ns. The Mach-Zehnder acts as a high-speed dimmer switch, providing NRZ modulated signals (AM signals, in reality) at 10 Gb/s. RZ signals provide performance advantages at 40 Gb/s, and Mach-Zehnder modulators to generate them became available in 2000 in prototype quantities.

GMPLS will definitely serve a purpose, through providing higher QoS for specified classes of service in what will become once more, heavily crowded fiber optic trunks.

Internet traffic doubled every ninety days from June 1999 through March 2001, with the majority of traffic arguably due to the sole application known as Napster®, used for peer-to-peer sharing of copyrighted MP3 music files for portable MP3 music file players such as Diamond Multimedia's Rio. [See communication timeline, in section 2.2 and Appendix A.] Many universities actually blocked access to Napster servers during this time just to prevent the complete overload of their Internet connections. With the government's shutdown of Napster®, in the spring of 2001, however, Internet traffic immediately plummeted, and many formerly lit lines went dark, as the amount of traffic no longer justified leasing as many fiber optic cables. By the spring of 2001, Internet traffic, as well as Internet revenue, both started to drop precipitously. Short of another 'killer Internet application' such as Napster® causing a rapid increase in Internet traffic, the need for GMPLS will likely remain weak for years (when viewed relative to the market conditions of 2002).

7.6 HUMAN INTERFACE ENGINEERING

A true measure of human interface engineering's effectiveness and ubiquity in enabling data networks for Spaceports and Ranges of the future will be when pervasively connected, universal, wireless, body-worn interface appliances for controlling simple data network functions and accessing communication links become the norm. The use of such body-worn appliances, assuming their widespread acceptance, must not preclude the use of long-established and standardized interfaces. This is especially true for performing more complicated tasks where existing, proven interfaces suffice and work well. Novelty for the sake of novelty must not be introduced at the expense of effectiveness.

Ultimately, data network users must work efficiently, and, if a hoary human-interface technique remains the most effective way to reduce confusion, increase efficiency, or improve productivity, there will ultimately be no reason for transitioning to a more-modern, confusing, human interface technique for the sake of novelty.

The key for developing acceptable human interfaces is to use standardized command and control interfaces, adding new functionality and technology only where existing methods of conveying information do not suffice. The future must contain much of what has been used in the past, although often with a decidedly new and different twist.

As an historical analogy, consider the introduction of stock tickers on Wall Street, originally named because of the distinct ticking sound early instruments made upon receiving telegraph signals containing stock prices. The first stock ticker was developed in 1867 by E. A. Calahan of the American Telegraph Company. This design was improved by Thomas Edison, who received a patent in 1871 for an improved paper

tickertape automatic repeater for stock exchange prices. Edison improved his design further (Figure 7-6), and printing telegraphs and stock tickers alone accounted for the first 40 of the 1,093 patents that Edison received throughout his long and productive career.

The ultimate outcome, of the pioneering work done by Edison and other inventors, was that stock tickers and ticker tape served to provide a sense of the minute-by-minute trades occurring on the trading floor for decades. Stock tickers brought true technological improvement to Wall Street.^{335,336} Ticker tape also entered the lexicon as an adjective, used to denote a specific type of parade used to honor heroes passing through the financial district of Manhattan.³³⁷ Yet, today, mechanical ticker tape machines, and ticker tape, have both long been relegated to the dustbin of history. The use of streaming tickers, rolling silently across the bottom of TV and Internet-connected computer screens continues to this day, albeit without the very sound that gave rise to the name given to the format itself. The rolling ticker data format remains the same; long after ticker tape itself has ceased to exist, to permit interfacing stock market data in a familiar way to the legions of stock market watchers. Although ticker tape is gone, its' underlying method of streaming information remains.³³⁸

In much the same way, although specific technologies may be replaced in the future on Spaceports and Ranges, the lesson from the past is that newly introduced technologies usually must continue to interface in familiar ways, to avoid confusing the human users.

³³⁵ <http://www.w-pro.com/edison/>

³³⁶ Over 5,000 of Edison's Universal Stock Tickers were ultimately produced, in what became Edison's first commercial success, and their widespread success established Edison as a notable inventor, and further provided him with Wall Street financier connections that funded additional developments at Edison's Menlo Park laboratory, which became known as The Invention Factory among the financiers.

³³⁷ Wi-Fi may very well enter common use not only as a description of a specific method of wireless interconnectivity, but also for a more generic method of becoming wireless-enabled within just a few years, as more and more use is made of the technology in the public.

³³⁸ Increasing information bandwidth in 1871 terms would have equated to sending information faster, the same as today, but specifically, in 1871, it most probably would have meant simply making ticker tape wider!



Figure 7-6 Thomas Edison's Universal Stock Ticker

Achieving acceptance of new human engineering interfaces requires a keen understanding of numerous computer-based information topics coupled with a deep appreciation of historical practices. Whatever the technologies are forthcoming in the near term, foreseen or not in this document, an underlying need will exist for keeping human interactions smoothly integrated with the technologies, if success is ultimately to follow. It is the hope that this document has accomplished its goals of keeping humans innately involved in achieving routine access to space.

8.0 PROPOSED RISM PHASE 2 (ECT) ACTIVITIES

During the RISM Phase I Project, the RISM team comprised of:

- NASA and NASA-contractor engineers and managers
- Aerospace leaders from Government, Academia, and Private Industry participating through the Space Based Range Distributed System Working Group (SBRDSWG)
- Members of the Advanced Range Technology Working Group (ARTWG) subgroups
- Members of the Advanced Spaceport Technology Working Group (ASTWG)

have together envisioned a future Spaceport and Range that builds on today's legacy cabled and wireless infrastructure and that additionally provides a seamless integration of emerging communication techniques.

As envisioned by these aerospace leaders, the future Spaceport and Range will constitute a single communication and data-networking environment and additionally will:

- Contain mobile, portable, and fixed elements
- Provide an always on, 24/7, communication environment
- Provide high bandwidths, achieved without wires or cables that will form the majority of new extensions to today's infrastructure, to permit flexible accommodating change, and to avoid stuffing more physical cables into the cable trays and ducts that exist today
- Be pervasively connected, in terms of linking wirelessly and without fibers (e.g., a "fiberless" extension to the existing infrastructure) nearly everything that is new or that is added to the Spaceport and Range environment
- Provide seamless connections to today's wired communications infrastructure, as well as to future systems
- Provide Data Assurance, comprised of:
 - Data Integrity (i.e., protection against tampering, whether intentional or unintentional)
 - Data Authentication (i.e., anti-spoofing functionality)
 - Data Availability (which can range from minor latency issues (timeliness) all the way to data unavailability)

- Data Ease-of-Use
- Data Security (i.e., protection of data content to unauthorized personnel)

The overarching conclusion from the RISM Phase I activities, culminating in this document, is that the future of Spaceport and Range communication and data networking will largely grow from the communications baselines that exist today. Although this is believed true, there are key missing technologies and areas where development must occur to permit the growth from today's infrastructure.

For the buried fiber optic cables and much of the infrastructure that is in place today, no recommendation is made for their removal or wholesale replacement. Rather, the growth that is foreseen is for the edge of the data network, involving the 'on' and 'off' ramps for data.

For FY03, the RISM project will be renamed ECT (Emerging Communication Technology) to describe better the R&D effort that will be occurring. The project will continue technology research (that resulted in a broad scope distributed range subsystem report in year one) through "drilling down" into the three key technology areas identified in the report:

- Free Space Optics (FSO)
- Ultra Wideband (UWB)
- Wireless Ethernet (Wi-Fi)

The emphasis in FY03 will be to ensure technology interoperability of future Space Based Range Distributed Subsystems by focusing on the areas that will likely provide the biggest rewards for early investment of resources, through identifying future Spaceport and Range technology shortcomings while there is still time to encourage inclusion of features in commercial products to reduce the cost of future hardware, software, and communication protocols. One of the key topics to be investigated is data assurance, comprised of data integrity, data authentication, data availability, data ease-of-use, and data security, overlaid over the three transport mechanisms of FSO, UWB, and Wi-Fi. The goal is to identify the fundamental shortcomings that must be filled in three of the most promising commercial communication technologies prior to integrating functions into an integrated future data network.

The objectives will be as follows:

- Continue bi-weekly working group telecons, to extract/provide knowledge from/to acknowledged aerospace leaders in academia, industry, and Government, thereby engendering a technology support infrastructure to support future commercial communication technology developments that include built-in features to reduce future Government hardware costs

- Establish a laboratory for evaluation of FSO, UWB, and Wi-Fi technologies
- Conduct tests for achieving a detailed technology investigation of FSO, UWB, and Wi-Fi technology to support high-speed, selectable security, & data connectivity needs for multiple applications
- Determine compatibility of these technologies with existing communication systems
- Investigate test exemplars from major vendors
- Determine performance thru laboratory & field tests, thereby establishing limits on communication range and electromagnetic compatibility of these technologies with existing communication systems
- Publish a report
 - Detailing the theoretical limitations
 - Documenting the measured test results
 - Identifying technology short comings and present a recommendation either for or against integrating these emerging technologies into future Spaceports and Ranges

9.0 RESEARCH CONTRIBUTORS

9.1 RISM BIOGRAPHICAL THUMBNAIL SKETCHES

Gary L. Bastin, Ph.D.

Dr. Gary Bastin, as RISM Technical Lead, was responsible for setting the vision of this project, for both the written document, as well as of the bi-weekly SBRDSWG telecons. He contributed heavily to the communication technology sections of this document.

William G. Harris, P.E.

Mr. William ‘Bill’ Harris, as RISM Task Order Lead, was responsible for the overall project. This included creating the RISM work plan, staffing the project, interfacing with the NASA customer, reporting progress, and managing most of the day-to-day activities. He established the initial outline for the final report and contributed heavily to the Range and Vehicle sections.

9.2 FIRSTWG / SBRDSWG PARTICIPANTS & AFFILIATIONS

The Range Information System Management (RISM) project facilitated a working group, the Space-Based Range Distributed Subsystem Working Group (SBRDSWG) which was later renamed the Future Integrated Range and Spaceport Technology Working Group (FIRSTWG).

The SBRDSWG helped to identify the current state of the art, and potential new technologies, for possible future use in communication system architectures that will provide data networking in support of Spaceports and Ranges.

SBRDSWG’s efforts were in addition to, and complimentary to, efforts of the ARTWG Communication Architecture Subgroup, as well as the efforts of the other ARTWG Subgroups, and of ASTWG.

Products from the RISM Project’s efforts (and SBRDSWG), such as candidate technologies and potential architectures, formally feed into the ARTWG Communication Architecture Subgroup for ARTWG, and into the ASTWG. These inputs will be evaluated in the same manner and process as the inputs coming from any other organizations or projects feeding information into ARTWG and ASTWG.

Working Group forums (and likewise initiatives, such as SBRDSWG) help the ARTWG, ARTWG subgroups, and the ASTWG “drill down” to technical details and levels that would otherwise not be possible.

In addition, pioneering work in determining potential technologies and architectures helps the ARTWG Technology Integration Steering Committee (the leadership and vision teams combined), as well as the ASTWG, focus their efforts toward identifying possible system architectures for the near term, mid term, and long term.

The RISM project (and SBRDSWG), along with other efforts such as the Extended Range Concept Definition Study being done by Booz/Allen/Hamilton for the California Space Authority, are all significant first steps helping to refine the ARTWG recommended architectures and technology focus areas. These efforts are helping the ARTWG establish national roadmaps by April '03.

Table 9-1 lists the SRBDSWG members and their affiliations. Although the contributions of the members listed herein are numerous in terms of their impacts on this document, all responsibility for any errors or other inaccuracies in this document reside solely with the authors, Dr. Gary Bastin and Mr. William Harris, and not with any other members of the working group.

Table 9-1 Future Integrated Range/Spaceport Technologies Working Group

First	Last	Affiliation
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Rick	Bailey	SMC/CWP
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George	Eleneical	L-M
Temel	Erdogan	Dynacs-KSC
Scott	Fagan	
CD	Forbes	Veridian
Larry	Freudinger	NASA-DFRC
Mark	Gardner	Florida Space Authority
Richard	Gassman	Harris
Larry	Gooch	California Space Authority

First	Last	Affiliation
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Bill	Harris	Dynacs-KSC
Kenneth	Heffner	45SW/SYR
Hal	Herring	CSR
Thomas	Hillyer	L-M
Mike	Hitch	Harris
Adrian	Hooke	NASA-JPL
Stewart	Jackson	FAA
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Steven	Kermer	NASA-GSFC
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Jason	Lyden	Harris
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Carl	McNutt	Harris
	mdo	<u>RTI</u>
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Rod	Morris	Viasat

First	Last	Affiliation
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Rich	Nelson	NASA-KSC
Matt	Olenick	Swales-KSC
Ron	Phillips	FSI/UCF
Don	Philp	Dynacs-KSC
Mike	Pleskach	Harris
D	Ponchak	NASA-GRC
Wayne	Powell	NASA-GSFC
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Charles	Puckett	SLRSC
Bill	Roeder	NASA-KSC
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John	Seybold	Florida Tech
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Dr. Jim	Simpson	NASA-KSC
Darin	Skelly	NASA-KSC
	Snyder	Eglin
Stan	Starr	Dynacs-KSC
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Marty	Waldman	Vandenberg
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10.0 ACKNOWLEDGEMENTS

Although there is always the risk of inadvertently forgetting someone, the RISM team nonetheless wishes to acknowledge especially the assistance and guidance provided by the following individuals, listed alphabetically. Without the continued support of these supporters who believed in the value of this project, this project could not have accomplished all its goals.

Name	Organization
Hugo Delgado	NASA-KSC
Eric Denson	NASA-KSC
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Special thanks go to the late Steve Schaefer, who passed away during this project at a much too early age. He was instrumental in establishing the shared-access computer drives to enable the RISM team to work efficiently and effectively in the course of this project.

11.0 **GLOSSARY****0**

(reserved)

1

10BaseT	10 Mb/s Ethernet, the first Ethernet standard
100BaseT	100 Mb/s Ethernet, also known as fast Ethernet
100BaseTX	100 Mb/s Ethernet over UTP or STP
100BaseT4	100 Mb/s Ethernet over Category 3, 4, or 5 cabled UTP. Does not support full duplex since four pairs of wires are required to interconnect data paths.
100BaseF	100 Mb/s Ethernet over fiber optic cable
100BaseFX	100 Mb/s Ethernet over MMF fiber optic cable
1000BaseX	1000 Mb/s Ethernet over fiber optic cable, also known as Gigabit Ethernet (See: 802.3z)
1000BaseT	1000 Mb/s Ethernet over TSP cable
1394	Firewire®; a high-speed serial digital interface; also known as i-link®, and as the IEEE 1394 -1995 standard
1.5G	First Generation and a half Wireless; analog based modulation services with limited digital functionality, such as 1.5 Way pagers that can only respond with canned ASCII messages (Yes, No, etc.) to SMS received messages.

2

24/7	Twenty-four hours a day, seven days a week; indicates continuous service
2G	Second Generation; Second Generation Wireless; wireless services utilizing digital techniques, in contrast to first generation wireless devices that analog modulation techniques
2.5G	Second Generation and a Half Wireless; wireless services that provide all the characteristics of 2G systems with some of the characteristics planned for 3G Systems
2 nd Gen	Second Generation RLV (deprecated), SLI (preferred)

3

3G	Third Generation; Third Generation Wireless; wireless services that provide roaming abilities among various systems, across national boundaries, with automatic billing, having integrated voice and data functionality, although with limited data throughput capability (typically < 35 Mb/s)
3GPP	Third Generation Partnership Program; a 3G Wireless partnership program

4	
4G	Fourth Generation; Fourth Generation Wireless; wireless services that provide all the characteristics of 3G Systems, with the additional ability to interact wirelessly with various other types of 4G devices, and which provide high speed data throughput (> 50 Mb/s)
5	
(reserved)	
6	
(reserved)	
7	
(reserved)	
8	
802.3	Wireless Ethernet (Wi-Fi) standard; in formal terms, the IEEE 802.11 WLAN Standard
802.11a	Wireless Ethernet (Wi-Fi) operating at speeds up to 54 Mb/s in the 5 GHz band
802.11b	Wireless Ethernet (Wi-Fi) operating at speeds up to 11 Mb/s in the 2.4 GHz ISM band
802.11b+	A non-standard, proprietary Wireless Ethernet ‘turbo-standard’ describing products sold only by D-Link Systems operating at speeds up to 22 Mb/s in the 2.4 GHz ISM band; 802.11b+ equipment is incompatible with all other vendors’ Wireless Ethernet products when operated in ‘turbo’ mode
802.11g	Wireless Ethernet (Wi-Fi) operating at speeds up to 54 Mb/s in the 2.4 GHz ISM band
802.11i	Wireless Ethernet (Wi-Fi) with TKIP-based encryption
802.15.4	An emerging IEEE standard for an ultra low-power consumption wireless technology known as Zigbee.
802.1X	An IEEE standard for passing EAP over a wired or wireless LAN that avoids having to package EAP within PPP; 802.1X accomplishes authentication, only, unlike full PPP, and also supports protocols other than TCP/IP (See: EAPOL, EAP, PPP)
802.3ae	10 Gb/s Ethernet-based LAN standard
802.3z	Gigabit Ethernet-based LAN standard
9	
(reserved)	
A	

AADC	Alaska Aerospace Development Corporation
AB	Air Base
ABM	Anti-ballistic Missile (Treaty)
ac	Alternating Current
ACME	Command Message tester
ACS	Assembly and Command Ship
A/D	Analog to Digital
AELS	Augmented Emergency Landing Sites
AEOS	Advanced Electro Optical System
AFB	Air Force Base
AFDTC	Air Force Development Test Center (Eglin)
AFETR	Air Force Eastern Test Range; also ETR; also ESMC;
AFFTC	Air Force Flight Test Center (Edwards AFB)
AFSCN	Air Force Satellite Control Network
AFSPACECOM	Air Force Space Command
AFSS	Autonomous Flight Safety System
AFWTR	Air Force Western Test Range
A/G	Air to Ground
AI	Artificial Intelligence
AJ	Anti-Jam
AK	Alaska
AL	Alabama
ALCOR	ARPA Lincoln C-Band Observable Radar
ALDF	Advanced Lightning Direction Finders
ALF	Auxiliary Landing Field
ALTAIR	ARPA Long-Range Tracking and Instrumentation Radar
ALTS	Aided Laser Tracking System
AMOS	Air Force Maui Optical Station
AN/FPQ-14	Missile Precision Instrumentation Radar (MIPIR)
AN/FPQ-15	Target Tracking Radar (TTR)
AN/FPQ-18	Ascension radar
ANGB	Air National Guard Base
AN/MPS-39	Multiple Object Tracking Radar (MOTAR)
AOA	Abort-Once-Around
AOR	Atlantic Ocean Region
AOV	Acquisition of Visual
APARS	Advanced Phased Array Radar System
APT	Aerial Propellant Transfer (in-flight re-fueling)
ARDC	Air Research and Development Command
ARDS	Advanced Range Data System
ARIA	Advanced Range Instrumentation Aircraft
ARPA	United States Defense Advanced Research Project Agency; also known as DARPA
ARPANET	Advanced Research Project Agency Network; a large computer WAN created by the United States Defense Advanced Research

Project Agency started in 1969 between UCLA and the Stanford Research Institute – it was the precursor to today’s Internet

ARC	Ames Research Center
ARSR	Air Route Surveillance Radar
ARTM-IS	Advanced Range Telemetry Integration and Support
ARTWG	Advanced Range Technology Working Group
AS	Anti-Spoofing (GPS)
ASC	Airspace Surveillance Center
ASCII	American Standard Code for Information Interchange
ASIC	Application Specific Integrated Circuit
AST	Airborne Surveillance Test bed
ASTE	Armament Systems Test Environment
ASTG	Aerospace Test Group
ASTWG	Advanced Spaceport Technology Working Group
ATDC	Advanced Technology Development Center LC#20
ATF	Aeronautical Tracking Facility
ATOTS	Advanced Transportable Optical Tracking System
AWG	Arrayed Waveguide Grating; an optical planar lightwave demultiplexer, used for separating DWDM signals, i.e., for providing optical drop functions
Az	Azimuth
B	
b	Bit, a binary digit, a ZERO or a ONE
b/s	bits per second
B	
BARSTUR	Barking Sands Tactical Underwater Range
BER	Bit Error Rate
BGP	Border Gateway Protocol; a router Ethernet protocol for provisioning MPLS
BIDDS	Base Integrated Data Distribution System
Bluetooth	Short range WPAN technology standard used for replacing cables
BM	Body Mounted
BMD	Ballistic Missile Defense
bps	bits per second
BPSK	Binary Phase Shift Keying; Bi-Phase Shift Keying
BW	Bandwidth
C	
C&DH	Control & Data Handling (STARS module)
C/A-Code	Coarse Acquisition Code (GPS)
C	Celsius

C	Centigrade
Cable Modem	A modem intended to provide two-way computer network operation over an existing cable TV system, usually using the DOCSIS standard.
CAD	Computer Aided Design
CANDOS	Communications & Navigations Demonstrations on Shuttle
Cat	Category; as in Cat-5 Ethernet cabling
CBD	Commerce Business Daily
CCAS	Cape Canaveral Air Station
CCF	Central control Facility (Eglin)
CCRS	Central Command Remoting System
CCSDS	Consultative Committee for Space Data Systems
CCTV	Closed Circuit Television
CD	Collision Detection
CD&SC	Communication Distribution & Switching Center
CFRSL	Central Florida Remote Sensing Lab (UCF)
CGLSS	Cloud to Ground Lightning Surveillance System
CH	Channel
CIGTF	Central Inertial Guidance Test Facility
cm	Centimeter
COMSEC	Communications Security
cps	Cycles Per Second
CSLA	Commercial Space Launch Act; A 1984 Law, amended in 1988 and again in 1998, governing the evolving role of Government launch providers and private launch providers within the United States
CSOC	Consolidated Space Operations Contract
CSMA	Carrier Sense Multiple Access (used in Ethernet)
CSMA/CD	Carrier Sense Multiple Access/Collision Detect (Ethernet technique)
CTS	Command Transmitter System
CY	Calendar Year (in contrast to FY)
CW	Continuous Wave (an unmodulated RF signal, usually a sine wave)
D	
D/A	Digital to Analog
D/L	Data Link
D/L	Downlink
DAC	Digital to Analog Converter
DARPA	United States Defense Advanced Research Project Agency; also known as ARPA (see ARPA, ARPANET)
Datacom	Data Communications; short-range communications of data; in opposition or in contrast with Telecom
dB	Decibel; $10 * \log$ (ratio of power levels), logarithm to base 10.
dBc	Decibels Referred to Carrier power
dBm	Decibels Referred to 1 MilliWatt

dBW	Decibels Referred to 1 Watt
dc	Direct Current
DCSS	Digital Communication Switching System
DDOT&E/RR	<u>Deputy Director, Operational Test and Evaluation/</u> Resources and Ranges
DE	Differentially Encoded
DEMUX	Demultiplexer
DFB	Distributed Feedback (type of laser)
DFRC	Dryden Flight Research Center
DHCP	Dynamic Host Configuration Protocol, Dynamic Host Control Protocol; a computer communications protocol; a TCP/IP protocol providing automatic host configuration
DISN	Defense Integrated Switching Network
DMA	Defense Mapping Agency
DME	Distance Measuring Equipment
DMNE	Digital Message Network
DMS	Decision Models and Simulation
DNA	Does Not Apply
DOAMS	Distant Object Attitude Measurement System
DOCSIS	Data over Cable Service Interface Specification; a Cable Modem protocol specification – DOCSIS includes networking support for computers, as well as HDTVs and set-top TV boxes
DoD	Department of Defense
DOF	Degrees-of-Freedom
DOP	Dilution-of-Precision
DOT&E	Director, Operational Test and Evaluation
DRCS	Digital Range Communication System
DRS	Data Relay Satellite
DRS	Data Relay Station
DRS	Digital Range Safety
DS	Data Strobe
DS-DE	Data Strobe, Differentially Encoded (digital signal format)
DSB	Defense Science Board
DSL	Direct Subscriber Line (high-speed computer interface over ordinary phone lines)
DSN	Deep-Space Network
DSSS	Direct Sequence Spread Spectrum. A modulation technique. Used on Wi-Fi IEEE 802.11b
DWDM	Dense Wavelength Division Multiplexing; the transmission of data by which multiple wavelengths of light, each carrying a separate data stream, are combined onto a single optical fiber and then separated at the receiving end. The spacing between optical wavelengths is 200 GHz or 100 GHz, and is moving towards 50 GHz spacing, for sending data through a single optical fiber.

E

EAFB	Edwards Air Force Base
EAP	Extensible Authentication Protocol; an extension used by some vendors (Cisco, <i>et al</i>) to secure a WLAN in addition to WEP; EAP is typically embedded inside of PPP (See: 801.1X)
EAPOL	EAP encapsulation Over LANs; the protocol used within 802.1X
ECAL	East Coast Abort Landing
ECL	Emitter Coupled Logic (logic family)
ECSS	European Cooperation for Space Standardization (an ESA standards group)
ECT	Emerging Communication Technologies
EDFA	Erbium Doped Fiber Amplifier (fiber optic amplifier)
EDW	Edwards
EFTS	Enhanced Flight Termination System
EIA	Electronic Industries Alliance (standards group)
EKV	Exo-atmospheric Kill Vehicle
EI	Elevation
ELEV	Elevation
ELS	Emergency Landing System
ELV	Expendable Launch Vehicle
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMF	Electromotive Force
EMI	Electromagnetic Interference (opposite of EMC)
EMP	Electromagnetic Pulse (post nuclear explosion event)
EMTE	Electromagnetic Test Environment
EOM	End of Mission
EoS	Ethernet over SONET; the mapping of Ethernet traffic streams over prior existing SONET infrastructure products to increase reuse of fielded equipment, reduce upgrade costs, and provide more efficient provisioning of bandwidth to end users (see VC)
ER	Eastern Range
ERDA	Erbium Doped Fiber Amplifier (fiber optic amplifier, EDFA preferred)
ERDAS	Eastern Range Dispersion Assessment System
ERIS	Exo-atmospheric Reentry Interceptor Subsystem
ERP	Effective Radiated Power
ES	Environment and Safety Directorate
ESA	European Space Agency
ESD	Electro-static Discharge (static electricity)
ESMC	Eastern Space and Missile Center (formerly AFETR); also ETR
ESSM	Evolved Seasparrow Missile
ET	External Tank
Ethernet	Ether Network; a network through which data originally passed through coaxial cables, analogous to radio transmissions through

the mythical Ether, which supposedly filled the vacuum of space and through which electromagnetic waves, including light and radio, passed in a pre-Einsteinian view of the universe. “Ether” thus implied multiplexed radio frequency transmission of data ‘wirelessly’ (even though sent through a coaxial cable) in place of sending individual signals on individual pairs of wires. “Wireless Ethernet” is thus seen, in some circles, much as a technical pun, implying an escape to freedom of coaxially contained wireless multiplexed data wanting to be free, in much the same way as if describing a wireless-wireless network, similar to “Wireless Cable”.

ETO	Earth to Orbit
ETR	Eastern Test Range (ESMC preferred)
ETROD	Eastern Test Range Operations Directive
EV	Expendable Vehicle
EW	Electronic Warfare

F

F	Fahrenheit
FAA	Federal Aviation Administration
FACA	Federal Advisory Council Act
FAR	Federal Aviation Regulation
FAR	Federal Acquisition Regulation
FCC	Federal Communications Commission
FCO	Flight Control Officer
FEA	Failure Effects Analysis
FEA	Fast Ethernet Alliance
FEC	Forward Error Correction; error detection and correction with block (e.g., Reed Solomon), convolutional (e.g. Viterbi) or other modern codes (Fire Codes, etc.)
FEC	Forward Equivalence Class; a method of identifying and classifying traffic flows according to QoS requirements within routers
Firewire	High-speed serial digital interface; also known as i-link, 1394, and IEEE 1394-5
FIRSTWG	Future Integrated Range and Spaceport Technology Working Group
FL	Florida
FMEA	Failure Modes and Effects Analysis
FPGA	Field Programmable Gate Array (logic chip)
FPS	Radar designation
fps	Feet per Second; velocity
fps ²	Feet per second squared; fps ² ; acceleration
FPQ-14	Radar designation

FSCM	Federal Supply Code for Manufacturers; a unique identifier for defense contractors and suppliers
FSO	Free Space Optical
Ft	Feet
Ft	Fort
FTE	Full Time Employee
FTP	File Transfer Protocol; an Internet protocol for transferring files error-free
FTS	Flight Termination System
FTSC	Flight Termination Standing Committee
FTSS	Flight Test Support System; FTSS was replaced by TGRS (See: TGRS)
FY	Fiscal Year
 G	
G	Giga (1,000,000,000)
G	Units of Gravitational Force
G/A	Ground-to-Air
G/T	Antenna Gain-to-Noise Temperature Ratio (measure of sensitivity); (pronounced as “G” over “T”); measured in dB
GaAs	Gallium Arsenide
GEO	Geostationary
GEODSS	Ground-based Electro-Optical Deep Space Surveillance
GFE	Government Furnished Equipment
GFT	General Force Theory (unification of Theory of Relativity with other theories)
GHz	GigaHertz (1000 MegaHertz)
GIS	Geographic Information System
Global Hawk	One specific UAV
gm	gram
GMT	Greenwich Mean Time (deprecated; UTC now preferred); the time on the prime meridian (at zero degrees longitude) in Greenwich, England
GOM	Ground Operations Manager
GPa	Giga Pascals (measure of the strength of materials)
GPS	Global Positioning System (see TGRS)
GSFC	Goddard Space Flight Center (Greenbelt, MD)
GSM	Global System for Mobile communication; the de facto encrypted wireless telephone service in Europe and over 120 countries worldwide (also available on a non-compatible equipment basis, in limited parts of the United States); two frequency bands are used: 900 MHz and 1800 MHz; encryption is provided through two algorithms, one of which is country dependant/definable and the

other of which is universally the same (these are the A3/A5 encryption algorithms)

GUT General Unified Theory (unification of Theory of Relativity; GFT preferred)
 GWEF Guided Weapons Evaluation Facility (Eglin)

H

H2 Hydrogen; specifically, molecular diatomic hydrogen in the normal associated state of two atoms of hydrogen bonded together in contrast to atomic hydrogen consisting of but one atom of hydrogen
 H2O2 Hydrogen Peroxide; (a non-cryogenic rocket propellant oxidizer)
 HAFB Holloman Air Force Base
 HAM Holloman Aero-Medical laboratory
 Handheld Portable Computer, such as a PDA
 HDMS Hawaii Digital Microwave System
 HDTV High Definition Television
 He Helium
 HELSTF High Energy Laser Systems Test Facility
 HHSTT Holloman High Speed Test Track
 HI Hawaii
 HOE Homing Overlay Experiment
 HPF Hypergolic Maintenance Facility
 HQ Headquarters
 HTHL Horizontal Takeoff – Horizontal Landing
 HTVL Horizontal Takeoff – Vertical Landing
 HWIL Hardware In the Loop
 Hz Hertz (Cycles Per Second)

I

ID Identification
 I&M Improvement and Modernization
 I/O Input/Output
 ICBM Intercontinental Ballistic Missile
 IEEE A non-profit, technical professional association of more than 377,000 individual members in 150 countries. The full name is the Institute of Electrical and Electronic Engineers, Inc., although the organization is most popularly known and referred to by the letters I-E-E-E ((Eye-triple-E).
 IETF Internet Engineering Task Force; for more information on the IETF, see their website at <http://www.ietf.org/>.
 IFLOT Intermediate Focal Length Optical Tracker

IIP	Instantaneous Impact Point; location where a missile will land, computed based on present ballistic and un-powered flight profiles
IGS	Inner Glide Slope
IGOR	Intercept Ground Optical Recorder
ILL	Instantaneous Landing Location; location where a missile will land (See IIP)
in	Inch
INMARSAT	International Maritime Satellite
IOP	Interoperability
IOS	Indian Ocean Ship (STDN)
IOS	Indian Ocean STDN Site
IP	Internet Protocol
IP	Intellectual Property
IP	Impact Point
IPF	Integration & Processing Facility
IPO	Initial Public Offering; the selling of stock in a company in order to raise money through conversion of a privately held company to becoming a publicly held company, and to provide an ‘exit strategy’ for VC funds (See VC)
IPSEC	Internet Protocol Security; a VPN implementing protocol based on encryption either complementary to, or competing with, MPLS
IPv4	Internet Protocol Version 4; a router protocol governed by RFC1812 (see RFC)
IPv6	Internet Protocol Version 6; a router protocol governed by RFC3146 that extends the Internet’s IP address space, permitting more computers to be connected to the Internet (see RFC)
ISA	Industry Standard Architecture; an older 16-bit PC expansion slot interface associated with IBM AT (286) era hardware (see PCI)
ISDN	Integrated Services Digital Network; an early voice, video and data service providing 64 Kb/s throughput over telephone lines, typically in two independent 64 Kb/s streams (for 128 Kb/s, total). (DSL is the logical successor.)
IRIG	Inter-Range Instrumentation Group
ISAR	Inverse Synthetic Aperture Radar
ISM	Industrial, Scientific, Medical, domestic (RF band reserved for serving these users)
ISP	Internet Service Provider
ISS	International Space Station
ISTEF	Innovative Science and TEchnology Facility
ITU	International Telecommunication Union; a European standards body founded in 1865, which became a United Nations agency in 1947
IWG	Interagency Working Group

J

J	Joule (SI Unit)
JAMI	Joint Advanced Missile Instrumentation
JDMTA	Jonathan Dickinson Missile Tracking Annex
JPL	Jet Propulsion Laboratory
JR	Junior
JSC	Lyndon B. Johnson Space Center (formerly MSC); Johnson Space Center
JBOS	Joint Base Operations and Support

K

k	Kilo (1,000)
KAL	Korean Airlines
kHz	KiloHertz
KLC	Kodiak Launch Complex
KSC	John F. Kennedy Space Center
KSC	Kennedy Space Center
KTF	Kauai Test Facility
KTM	Kineto Tracking Mount
KTS	Kwajalein Test Site
kW	KiloWatt
kWh	KiloWatt Hours

L

L1	Link 1 (GPS) at 1575.42 MHz
L2	Link 2 (GPS) at 1227.6 MHz
L5	Link 5 (GPS) at 1176.45 MHz
LAN	Local Area Network
LASER	Light Amplification through the Stimulated Emission of Radiation
LASS	Launch Area Support Ship
LATS	Launch Area Theodolite Systems
LBS	Location Based Services; a protocol supported by the LIF
LBTS	Large Blast Thermal Simulator
LC	Launch Complex
LCC	Launch Control Center
LDP	Label Distribution Protocol; an MPLS router protocol
LEO	Low Earth Orbit
LER	Label Edge Router; an MPLS based router on the edge of the network that controls traffic entering and leaving the MPLS network; (see LSR)
LHCP	Left Hand Circularly Polarized
LHe	Liquid Helium

LH2	Liquid Hydrogen; a cryogenic propellant fuel
LIDAR	Light/Laser Radar
LIF	Location Interoperability Forum (its functionality is absorbed into OMA)
L-M	Lockheed Martin Company
LMSO	Lockheed Martin Space Operations
LNA	Low Noise Amplifier
LN2	Liquid Nitrogen
LO	Local Oscillator; an oscillator used to translate the frequency of a signal going into an RF mixer; can be either crystal controlled or a synthesizer (See PSD)
LO2	Liquid Oxygen (LOX); a cryogenic propellant oxidizer.
LOS	Line of Sight
LOS	Loss of Signal
LOSC	Launch Operations Support Contract
LOV	Loss of Visual
LOX	Liquid Oxygen (LO2); a cryogenic propellant oxidizer.
LPI	Low Probability of Intercept. A desirable feature of some DSSS signals
LPLWS	The Launch Pad Lightning Warning System
LPT	Low Powered Transceiver (STARS module)
LSP	Label Switched Path; a virtual path through an MPLS network
LSR	Label Switch Router; an MPLS based router located at other than on the edge of an MPLS network; (see LER); an intermediate router in an MPLS network
LVDS	Low Voltage Differential Signaling (digital signaling format)

M

m	
M	Mega (1,000,000)
M	Meter
mA	Milli-Ampere (one thousandth of a Amp)
MAC	Military Airlift Command
MAC	Media Access Control (layer of OSI, see OSI)
MAN	Metro Area Network (contrasts with LAN (smaller) and WAN (bigger))
Manned	Containing a staff of human(s) aboard a vehicle (deprecated; the term 'crewed' is now preferred)
MARSS	Meteorological and Range Safety Support
MASER	Microwave Amplification through the Stimulated Emission of Radiation; a LASER technology precursor/predecessor
MATS	Multimode Automatic Tracking Systems
Mb/s	Megabits per Second
MCBR	Mobile C-band Radar

MCC-DOD	Mission Control Center-DOD
MCC-H	Mission Control Center-Houston
MCC-K	Mission Control Center-Kennedy
MCC-NASA	Mission Control Center-NASA
MDI	Miss Distance Indication
MFCO	Main Flight Control Officer
MHz	MegaHertz (one million cycles per second)
MIDDS	Meteorological Interactive Data Display System
MIDI	Miss Distance Measurement Instrument
MILA	Merritt Island Launch Annex
MIRACL	Mid-Infrared Advanced Chemical Laser
MK	Mark
MLP	Mobile Launch Platform
MMF	Multi-mode fiber (type of fiber optic cable)
MMH	Monomethyl hydrazine (a hypergolic rocket propellant fuel)
MMS	Multimedia Messaging Service; a wireless standard
MMW	Millimeter Wave Radar
MOC	Metric Optics Control
MOL	Manned Orbiting Laboratory
MOTIF	Maui Optical tracking and Identification Facility
MOTR	Multiple Object Tracking Radar
MOTS	Mobile Optical Tracking System
MPIR	Missile Precision Instrumentation Radar (AN/FPQ-14)
MPLS	Multi-Protocol Label Switching; MPLS is an internationally standardized protocol that is not vendor-specific and which is an advanced way to deploy VPN connections with QoS requirements to large numbers of users simultaneously (see BGP); MPLS is sometime known as Multiprotocol Tag Switching (Cisco's original proprietary term for the technology) as well as Multiprotocol Lambda Switching (a futuristic private wavelength method of meeting QoS requirements); a competing but sometimes complementary technology to IPSEC for providing VPN connections
MRTFB	Major Range and Test Facility Base
MSA	Multi-Source Agreement (a fiber optic industry practice, of which many exist for various technologies: XAUI, XFP, XGP, to provide common interface modules and interfaces.)
MSBLS	Microwave Scanning Beam Landing System
MSBLS-GS	Microwave Scanning Beam Landing System – Ground Station
MSBLS-JR	Microwave Scanning Beam Landing System – Junior
MSC	Manned Spacecraft Center (changed to JSC)
MSC	Meteorology System Computers
MSFC	George C. Marshall Space Flight Center; Marshall Space Flight Center
MSFN	Manned Space Flight Network
MSN	Mission

MSS	Meteorological Sounding System
MSSS	Maui Space Surveillance Site
MTBF	Mean Time Between Failures
MTD	Materiel Test Directorate
MTS	Mobile Telemetry System
mV	MilliVolts (one thousandth of a Volt)
mW	MilliWatt (one thousandth of a Watt)

N

N2	Nitrogen
N2H4	Hydrazine
N2HO4	Nitrogen Peroxide
N2O4	Nitrogen Tetroxide; (a hypergolic rocket propellant oxidizer)
NACA	National Advisory Committee for Aeronautics
NAS	National Airport System
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NAT	Network Address Translation (Ethernet re-addressing)
NAWCWD	Naval Air Warfare Center Weapons Division
NAWS	Naval Air Weapons Station
NBM	Navy Ballistic Missile
NBVC	Naval Base Ventura County
NCC	Network Control Center
NF	Noise Figure
NH3	Ammonia
NH4	Hydrazine
NIC	Network Interface Card (Ethernet card, typically, at present. Historically NICs often referred to other protocols, too.)
NISN	NASA Integrated Services Network
NLDN	National Lightning Detection Network
NM	Nautical Miles
nm	Nanometer
NMD	National Missile Defense
NOP	North Oscura Peak
NOTS	Naval Ordnance Test Station
NRA	NASA Research Announcement
NRO	National Range Operations Directorate
NRTF	National RCS Test Facility
NS	Naval Station
NSF	Naval Supply facility
NRZ	Non-Return-to-Zero
NRZ-L	Non-Return-to-Zero Level
NSC	National Security Council
NWAD	Naval Warfare Assessment Division

NWTRC

Naval Western Test Range Complex

O

O ()	Big ‘Oh’ notation; a mathematical measure of complexity; a mathematical scale for comparing implementation difficulties among different mathematically intensive algorithms; the argument of the Big ‘Oh’ function is the measure of the complexity, with typical arguments being n , n^2 , n^3 , etc., and where the lower the power of the exponent, the lower the implementation complexity; algorithms having higher orders of complexity may be impossible to scale upward with existing or even future technologies
O ₂	Oxygen; specifically, molecular diatomic oxygen in the normal associated state of two atoms of oxygen bonded together in contrast to atomic oxygen consisting of but one atom of oxygen
OADS	Type of radar
OC	Optical Carrier
OC-3	Data Rate of 155Mb/s (155.52 Mb/s = 3 x 51.84 Mb/s)
OC-12	Data Rate of 622 Mb/s (622.08 Mb/s = 12 x 51.84 Mb/s)
OC-48	Data Rate of 2.5 Gb/s (2488.32 Mb/s = 48 x 51.84 Mb/s)
OC-192	Data Rate of 10 Gb/s (9953.28 Mb/s = 192 x 51.84 Mb/s)
OC-768	Data Rate of 40 Gb/s (39813.12 Mb/s = 768 x 51.84 Mb/s)
OC-3072	Data Rate of 160 Gb/s (159252.48 Mb/s = 3072 x 51.84 Mb/s)
OFDM	Orthogonal Frequency Division Multiplexing; a modulation technique; used on Wi-Fi 802.11a.
OGS	Outer Glide Slope
OIF	Optical Internetworking Forum (fiber optic equipment standards group)
OIS	Operational Intercommunication System
OLE	Object Linking and Embedding; a method by which Windows 3.1 (and later Windows versions) running on PCs were able to provide data sharing between applications running simultaneously on the same computer, thereby preventing the need for the re-typing of data from one software application into another
OMA	Open Mobile Alliance; an organization with the goal of removing existing barriers and permitting the global seamless application interoperability for mobile wireless users
ONE	Logical one, “1”
OPF	Orbiter Processing Facility
OSI	Open System Interconnection; a 7-layer abstraction model of network protocols, extending from Layer 1, or the Physical Layer, through Layer 7, or the Application Layer.
OSTP	Office of Science and Technology Policy
oz	Ounce

P

PAA	Phased Array Antenna
PACFLT	Pacific Fleet
PAFB	Patrick Air Force Base
PAM	Pulse Amplitude Modulation
PAM-A	PAM, Atlas-Centaur Class Spacecraft
PAPI	Precision approach Path Indicator
PAWS	Public Aural Warning System
PC	Personal Computer, usually an IBM compatible clone, although technically a Macintosh® by Apple (i.e., a Mac) is also a PC as well, although in common usage PCs and Macs are considered different
PCC	Portable Computer Card; PC Card; Personal Computer Card; a noun used to augment meaning, as in PCC/PCMCIA used to indicate a Portable Computer Card supporting the PCMCIA standard
PCL	Passive Coherent Locator; a passive RADAR utilizing commercial FM and TV broadcasts as the illumination source; Silent SENTRY (Lockheed-Martin’s PCL system.)
PCI	Peripheral Component Interconnect; a 32-bit or 64-bit, clock-synchronous PC expansion slot interface governing plug-in cards that comes in two basic types (full size and half-sized or smaller) and numerous variations, and which supports the older ISA interface (see ISA). Originally a local bus, PCI is presently supported on nearly all current generation PCs, in both a 124-pin and in an expanded 188-pin configuration, independent of processor type.
PCM	Pulse Code Modulation
PCMCIA	Personal Computer Memory Card International Association. A PC interface standard for small, credit-card sized devices, which originally was used only for adding memory to portable computers (laptops), but is now used for many types of devices (Ethernet cards, Wi-Fi cards, etc.) Always pronounced as individual letters, and typically used as an adjective, as in “PCMCIA slot” or “PCMCIA card”
P-Code	Precise Code (GPS)
PCS	Personal Communications Services; a wireless telephone service technology (also known as digital cellular) that emphasizes personal service and user mobility to a larger degree than needed solely to provide service to car-mounted wireless phones through using larger numbers of relay stations to base stations; PCS operates in the 1850 MHz to 1990 MHz band in the United States; PCS systems operate variously with CDMA, TDMA, and GSM

	techniques depending on which PCS service provider provides one's service
PDA	Personal Digital Assistant (a small portable computer intended to be carried continuously)
PECL	Positive ECL (ECL with positive voltage swings, pronounced as "peckle")
PHY	Physical; often used as a noun to denote Layer 1, the Physical Layer, of the OSI, as in "WAN PHY"; usually pronounced as 'PHI' with an 'I' sound, not an "E" sound
PIGOR	Patrick IGOR Optics site
PIREP	Pilot Reports
PM	Phase Modulation
PMRF	Pacific Missile Range Facility
PN	(1) Pseudo-Noise, pronounced as individual letters; (2) Pseudo-Random ($2^N - 1$ length digital sequence of ONES and ZEROs)
POTS	Plain Old Telephone System; plain old telephone lines, based on copper wires; pronounced as one word 'pots'
PPP	Point-to-Point Protocol; an early Internet protocol originally used solely for dial-up access, but which continues to be used by some ISPs for DSL and Cable Modem user authentication through sending PPP over Ethernet (Ethernet, in turn, can be sent over SONET, ATM, and a multitude of other OSI Layer 1 and 2 protocols); PPP has also become part of Layer 2 Tunneling protocol used in Microsoft's Window 2000 and later for secure remote access; PPP also now commonly incorporates EAP within PPP; 802.1X has replaced PPP in some applications (See: EAP, 801.1X, OSI)
PRIMES	Preflight Integration of Munitions and Electronic Systems
PRN	Pseudo-Random Noise ('PN noise' is more commonly seen than PRN)
PSD	Power Spectral Density; a source of degradation for BER when introduced into a system by synthesizer or oscillator phase noise
PSK	Phase Shift Keyed
Q	
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying

R

R&D	Research and Development
Radius	RADIUS; Remote Authentication Dial-in User Service; a remote user authentication protocol
RADOT	Recording Automation Digital Optical Tracker
RADS	Radar Acquisition Data System
RAM	Rolling Airframe Missile
RAMS	RATSCAT Advanced Measurement System
RAMS	Radar Cross Section Advanced Measurement System
RATSCAT	Radar Target Scatter
RCC	Range Commanders Council
RCC	Range Control Center
RCS	Radar Cross-Section
RCV	Receive
RCVR	Receiver
RDT&E	Research, Development, Test and Evaluation
RF	Radio Frequency; often used as an adjective implying “analog” with a meaning in practice that is opposite to the adjective “digital”. RF, however, implies operation at a higher frequency than baseband analog, hence the term RF/Analog is sometimes used.
RFA	RF Authorization (Frequency)
RFC	Request for Comment; a standard nested set of protocols governing the Internet dating back to the ARPANET
RFI	Radio Frequency Interference
RHVTS	Ruggedized High Volume Tracking System
RICS	Remote Instrument Control System
RISM	Range Information Systems Management
RLV	Reusable Launch Vehicle
RMI	Republic of the Marshall Islands
ROC	Range Operations Center
ROCC	Range Operations Control Center
ROTI	Recording Optical Tracking Instrument
ROTR	Type of radar
RP-1	Refined Petroleum One (a fuel)
RSG	Range Safety Group
RSO	Range Safety Officer
R/S TV Vans	Range Safety TV Vans
RTDPS	Real Time Data Processing System
RTLS	Return to Launch Site
RTS	Remote Tracking Station
RTS	Reagan Test Site (Kwajalein)
RTSC	Range Technical Support Contractor
RX	Receiver
RZ	Return-to-Zero

S

s

SA	Selective Availability
SAC	Strategic Air Command
SATCOM	Satellite Communication
SATMS	Space & Air Traffic Management System
SBI	Space Based Initiative
SBR	Space Based Range
SBRA	Space Based Range Architecture
SBRDS	Space Based Range Distributed Subsystems
SBRDSWG	Space Based Range Distributed Subsystems Working Group
SCAT	Spacecraft Assemblies Transfer
SCDS	Space Communication and Data Systems
SCI	Santa Cruz Island
SCPS	Space Communication Protocol Standards
SDH	Synchronous Digital Hierarchy; a mostly European fiber optic communications ITU standard for synchronous data transmission over fiber optic cables; the North American equivalent is SONET (See SONET); SDH defines a standard data rate of 155.52 Mb/s, known as STS-3 at the electrical level and STM-1 at the optical level, which are all equivalent to SONET's OC-3 data rate
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization
SE	Space Elevator
SERDES	Serializer-Deserializer (a fiber optic transponder function)
SFF	Small Form Factor
SHF	Super High Frequency
Si	
SiGe	Silicon Germanium (semiconductor technology)
Silent SENTRY	Lockheed-Martin's PCL system (See PCL)
SLBM	Submarine Launched Ballistic Missile
SLC	Space Launch Complex
SLF	Shuttle Landing Facility
SLI	Space Launch Initiative; preferred over 2 nd Gen
SLRSC	SpaceLift Range System Contracts
SLV	Space Launch Vehicle
SM	Standard Missile (Navy)
SMF	Single-mode fiber (type of fiber optic cable)

SMS	Short Message Service; a 2G or 2.5G protocol for sending short ASCII messages up to 160 characters (224 characters if using 5-bit mode) to cell phones or pagers from an Internet-connected computer or other e-mail account; many SMS services limit message lengths for their users to slightly more than 100 characters, depending on their exact system overhead and addressing details that consume some of the allowed 160 characters; SMS systems typically operate wherever cell phone coverage is available; many older SMS systems are 1.5 way (canned responses, only) whereas newer SMS systems are 2 way (2-way functionality depends on user equipment capability); SMS is integral to GSM phone systems; SMS differs from paging in that SMS systems hold messages for several days until user equipment is turned on, and provide coverage across all of North America, for example, whereas pagers do not guarantee delivery of pages
SNI	San Nicolas Island
SNORT	Supersonic Naval Ordnance Research Track
SOCC	Satellite Operations Control Center
SOHO	Small Office, Home Office; an adjective that refers to small businesses and home-based offices/businesses as a market segment
SONET	Synchronous Optical Network (fiber optic protocol); a mostly North American fiber optic communications ANSI standard for synchronous data transmission over fiber optic cables created by Bellcore in the 1980's (See: SDH)
SOTR	Single Object Tracking Radar
SPARC	Single Point Acquisition and Radar Control
SPARS	Sensor Positioning and Read back System
SPF	Single Point Failure
SPFA	Single Point Failure Analysis
SPFP	Single Point Failure Potential
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SRS	Spaceport Range Systems
SRSS	Shuttle Range Safety System
SSCC	Space Station Control Center
SSID	Service Set Identifier; the first line of defense in securing a Wi-Fi access point against roaming wireless intruders
SSL	Secure Socket Layer (web browser security protocol)
SSP	Space Shuttle Program
SSPF	Space Station Processing Facility
SSTO	Single Stage To Orbit
SSV	Space Shuttle Vehicle
STA	Shuttle Training Aircraft
STARS	Space-Based Telemetry and Range Safety
STARS	An Air Force Missile
STARS	SpaceLift Operations Telemetry Acquisition and Reporting System

STDN	Space Tracking and Data Network
STDN	Spaceflight Tracking and Data Network
STGT	Second TDRSS Ground Terminal
STP	Shielded Twisted Pair (cable shielding description)
STS	Space Transportation System (Space Shuttle)
STV	Space Transfer Vehicle
SV	Space Vehicle (e.g., a GPS satellite)
SWR	Standing Wave Ratio

T

T-	Time Prior to Launch (T minus)
T-0	Time Zero, T minus zero
T-0	Takeoff
T&E	Test & Evaluation
TAC	Kennedy Space Center Landing Site, Florida
TACAN	Tactical Air Navigation
TAL	Transoceanic Abort Landing
TAS	Telemetry Acquisition Systems
TAS	Telemetry Antenna Subsystem
TAS	Tether Applications in Space
TAS	True Airspeed
TAV	Trans Atmospheric Vehicle
TBD	To Be Determined
TBD	To Be Defined
TBD	To Be Developed
TCF	Telemetry Collection Facility
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol; a computer communication protocol for communicating over the Internet
TDC	Telemetry Data Center
TDR	Tracking and Data Relay
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System; NASA's primary communication system
Telecom	Telecommunications; long-range communications of data; in opposition or in contrast with Datacom
TGRS	Translated GPS Range System; Translated Global Position System Range System; TGRS replaced FTSS (See: FTSS, GPS)
THAAD	Theater High Altitude Area Defense
THEL	Tactical High Energy Laser
TIA	Telecommunications Industry Association
TKIP	Temporal Key Integrity Protocol; a 2 nd generation Wi-Fi encryption technique, either replacing or augmenting WEP,

	depending on the ultimate decisions of vendors to provide true Wired Equivalence Privacy for Wireless Ethernet
TLM	Telemetry (deprecated; TM is preferred for new systems)
TM	Telemetry
TM	Technical Memorandum
TMD	Theater Missile Defense
TMS	Transport Management System
TMV	Telemetry Mobile Van
TOPS	Transistorized Operations Phone System
TPQ	Radar designation
TRADEX	Tracking and Discrimination Experiment
TRS	Thermal Radiation Source
TSPI	Time Space Position Information
TTARS	Transportable Telemetry Acquisition and Relay System
TTAS	Transportable Telemetry Acquisition Systems
TTR	Target Tracking Radar
TTY	Teletype
TU	Terminal Unit; a baseband to digital interface, providing two-way communications capability – often uses RS-232 or RS-422 for the digital interface protocol
TURFTS	TDRSS User RF Test Set (See TDRSS, RF)
TV	Television
TVOC	TV Operations Center
TW	Traveling Wave
TWG	Technical Working Group
TWT	Traveling Wave Tube
TWTA	Traveling Wave Tube Amplifier
TX	Transmitter
TXCVR	Transceiver; a radio consisting of a transmitter and receiver, with, strictly speaking, sharing of intermediate frequency chains (filters, amplifiers, etc.) through the re-use of common circuits for both transmit and receive functions
TX/RX	Transmitter/Receiver; a radio consisting of a transmitter and receiver with no re-use of common circuits shared between transmit and receive functions
 U	
UAV	Unmanned Aerial Vehicle; Un-crewed Aerial Vehicle
UDS	Universal Documentation System
UHF	Ultra High Frequency
UK	United Kingdom
Unmanned	Containing no human crew (recently deprecated; un-crewed or uncrewed now often preferred)
UPLK	Uplink

UPTLM	Uplink Telemetry
UPS	Uninterruptible Power Source
us	micro-second (a millionth of a second); the ‘u’ can be also written with the Greek letter ‘mu’, i.e., ‘μ’
USA	United States of America
USAF	United States Air Force
USB	Universal Serial Bus (personal computer interface)
USN	United States Navy
USNS	United States Naval Ship
USS	United States Ship
UTC	Universal Time Coordinated (formerly GMT)
UTLM	Up Telemetry
UTP	Unshielded Twisted Pair (cable shielding description)
UV	Ultra-violet (electromagnetic wavelengths from 280 nm – 400 nm)
UV-A	Ultra-violet A (EM wavelengths from 320-400 nm, not absorbed by ozone)
UV-B	Ultra-violet B (EM wavelengths from 280-320 nm, normally absorbed by ozone)
UVS	Unmanned Vehicle System
UWB	Ultra Wideband (impulse modulation technique)

V

VA	Volt Ampere
VAB	Vehicle Assembly Building
VAFB	Vandenberg Air Force Base
VC	Virtual Concatenation; an EoS technique for provisioning SONET pipes on an OC-1/STS-1 or OC-3/STS-3 basis, providing more efficient bandwidth utilization
VC	Venture Capital or Venture Capitalist; refers to a general limited liability partnership method for funding startups, typically providing funds in exchange for partial ownership and one or more director slots on the board of directors for a new company. VCs always have an ‘exit strategy’ to sell their ownership through an IPO. (See IPO)
VCSEL	Vertical Cavity Surface Emitting Laser
VERLORT	Very Long Range Tracking Radar
VHF	Very High Frequency
VLAN	Virtual Local Area Network (examples: Wi-Fi roaming between access points without re-authentication; reconfiguring Ethernet LANs to provide grouping by some pre-determined methodology)
VLF	Very Low Frequency
VLS	Vandenberg Launch and Landing Site
VNE	Video Network Element
VPN	Virtual Private Network

VSWR	Voltage Standing Wave Ratio
VTA	Vehicle Test Area
VTR	Versatile Tracking Mount
VTS	Vandenberg Tracking Station
VTHL	Vertical Takeoff – Horizontal Landing
VTVL	Vertical Takeoff – Vertical Landing
VWFC	Very Wide Field Camera
VWG	Verification Working Group

W

W	Watt
WA	Wide Angle
WAN	Wide Area Network
WAN/IU	Wide Area Network Interface Unit
WAP	Wireless Application Protocol; a protocol for supporting wireless communication across differing wireless networking standards; WAP functionality has largely been absorbed into OMA (see OMA)
Warchalking	An underground low-tech Wireless Ethernet fad commencing in June 2002 in London used for marking Wireless (i.e., ‘War-less’) Ethernet hotspots in chalk on sidewalks for digital hobos, analogous to the hobo codes used in America in the 1930’s to indicate information regarding dogs, food handouts, and other items of interest to hobos. Warchalking spread across high-tech geek hangouts within a matter of days to various locations in California, New York City, and other high-tech hotbeds around the world. Warchalking itself is a wordplay on “War-less” Ethernet and ‘wardialing’, an earlier term made popular in the 1980’s in the movies, describing how computer users obtained surreptitious access to dial-up modem lines to gain Internet access through dialing through entire city telephone directories, in order to find modem lines. (See Wi-Fi, 802.11b, WISP.)
WEA	Weather
WEAP	Wireless Ethernet Access Point
WECA	Wireless Ethernet Compatibility Alliance (Wi-Fi standards group)
WEFAX	Weather Facsimile
WEP	Wired Equivalent Privacy (Microsoft’s definition); Wireless Encryption Protocol (sometimes deprecated); a first generation Wi-Fi security encryption standard, perhaps to be augmented with TKIP or other proprietary security protocols
WFF	Wallops Flight Facility
WG	Wave Guide
WGS	World Geodetic System
Wi-Fi	Wireless Ethernet, IEEE 802.11 protocol; (see Ethernet).

WISP	Wireless Internet Service Provider
Wireless Cable	The transmission of cable TV multi-point served content signals, over wide areas, using free-space microwave frequency transmitted signals, distributed using multi-point distribution methods.
WLAN	Wireless LAN; Wireless Local Area Network
WNA	Wireless Network Adaptor. A NIC device, typically in a PCMCIA card format.
WNCC	Wheeler Network Communications Control
WPA	Wireless Protocol Analyzer; a security tool used to search for rogue (or unauthorized) WEAP devices
WPAFB	Wright Patterson Air Force Base
WPAN	Wireless Private Area Network (e.g., Bluetooth)
WPM	Words Per Minute
WSC	White Sands Complex
WSGS	White Sands Ground Station
WSGT	White Sands Ground Terminal
WSMC	Western Space and Missile Center
WSMR	White Sands Missile Range
WSSH	White Sands Space Harbor
WTR	Western Test Range
WX	Weather

X

X	
XAUI	10 Gb/s Attachment Unit Interface (“zowie”, a high speed interface standard)
XCVR	Transceiver
XFI	10 Gb/s Interface for Multi-Source Agreement governed XFP Modules
XFP	10 Gb/s Small Form Factor (SFF) Pluggable Multi-Source Agreement Module
XGP	10 Gb/s Interface for XAUI Modules
XMT	Transmit
XMTR	Transmitter
XOR	Exclusive-OR (logic function)
XPNDR	Transponder (TX/RX with clock and data recovery functions, for fiber optic use)
XPNDR	Transponder (repeat back transmitter connected to a receiver)
XPNDR	Transponder (telemetry transmitter)

Y

Y-Code Encrypted P-Code (GPS)

Z

Z Impedance

ZERO Logical zero, “0”

Zigbee An emerging IEEE standard for an ultra-low power consumption wireless technology. (See 802.15.4)

APPENDICES

- A. Timelines**
- B. Launch Centers & Ranges**
- C. Theoretical Basis Of Railgun Physics**
- D. Shuttle Landing Sites**

A. TIMELINES

A.1 AEROSPACE

Table A-1 presents a timeline of key aerospace-related events that are of importance to future Spaceports and Ranges.

Major milestones, which changed man’s perception of aerospace flight most drastically, are identified in **bold**. This list is by no means comprehensive. Rather, its purpose is merely as an in-depth and necessary prologue for understanding future trends and for envisioning and understanding likely Spaceport and Range needs of the future.

Table A-1 Aerospace Timeline

Date	Events	Range	Vehicle
12/17/03	Wright Brothers - First powered flight	Kitty Hawk, NC	Wright Flyer
3/16/26	Robert Goddard tests worlds first liquid fuel rocket	Auburn, MA	
5/20/27	Charles Lindbergh - first solo, nonstop transatlantic flight	Atlantic Ocean	Sprit of St. Louis
1945	United States Army Ordnance seized 300 carloads of V-2 components and 115 German rocket specialists, led by Wernher von Braun. First located in Fort Bliss, Texas, and White Sands, New Mexico.	White Sands	V-2
1946	V2 testing begins	White Sands	V-2
5/29/47	Modified V-2 went the wrong way and landed in a cemetery south of Juarez, Mexico adding to the decision to move missile testing to Cape	White Sands	V-2
10/14/47	Chuck Yeager First supersonic flight	Edwards	Bell X-1
9/1/48	Banana River Naval Air Station transferred to Air Force	Patrick AFB	
1949	Eastern Range Established	Joint Long Range Proving Grounds establish at Cape Canaveral	
10/28/49	Army Ballistic Missile Agency moved from Fort Bliss, TX to Redstone Arsenal at Huntsville, Alabama.	White Sands	

Date	Events	Range	Vehicle
1950	Government obtains remainder of Cape from private owners	Cape Canaveral	
6/20/50	First launch pad completed at Cape	Cape Canaveral	Bumper 7 (V-2 + Corporal)
7/19/50	First launch attempt from ETR	Cape Canaveral	Bumper 7 (V-2 + Corporal)
7/24/50	First launch from ETR	Cape Canaveral	Bumper 8 (V-2 + Corporal)
6/30/51	Patrick AFB became Air Force Missile Test Center.	Patrick AFB	
6/30/51	Cape became Cape Canaveral Missile Test Annex joining the Navy's Point Mugu, CA and the Army's White Sands, N.M.	Cape Canaveral, Point Mugu, White Sands	
7/21/51	Bahamas Long Range Proving Ground Agreement with Great Britain	Cape Canaveral + Point Jupiter, Florida; Grand Bahamas Bank; and Grand Turk Island.	
1953	Redstone testing begins	Cape Canaveral	Redstone
10/08/55	Jupiter Program begins - Joint Army-Navy Ballistic Missile Committee	Cape Canaveral	Jupiter
1955	Telemetry: 4 RF links & 215 measurements	Cape Canaveral	Jupiter
10/8/56	Navy pulls out of Jupiter program and continues development of Polaris		Polaris
11/26/56	All long range missiles transferred from Army to Air Force		Jupiter
10/4/57	Sputnik launched by Russians	Russia	R-7
1/3/58	Explorer-1 First US launched satellite in space	Cape Canaveral	Juno-1
3/17/58	2nd Satellite launched by US (still in orbit)	Cape Canaveral	Vanguard
10/1/58	NASA formed out of NACA		
1959	Early launch success	Cape Canaveral Launch Success: 95%	

Date	Events	Range	Vehicle
1960	Range Instrumentation ships become operational	ETR / WTR	
1960	NASA opens Bermuda tracking site	ETR	
3/15/60	Army's Development Operations Division (Wernher von Braun and group) and Saturn program are transferred to NASA; Huntsville installation is renamed Marshall	Marshall	Saturn
4/12/61	Yuri Gagarin First man in space	Russia	Vostok
5/5/61	Alan Shepard - 1st US manned suborbital flight Mercury	Cape Canaveral	Redstone (Vehicle had 2 RF links and 116 measurements)
5/25/61	Kennedy's challenge to go to the moon	Cape Canaveral	
7/21/61	Gus Grissom 2nd US manned suborbital flight Mercury	Cape Canaveral	Redstone
8/24/61	NASA selects Merritt Island for spaceport to moon	KSC	Saturn
1961	Saturn Program starts	Cape Canaveral	Saturn C-1
1961	Telemetry: 8 RF links & 560 measurements	Cape Canaveral	Saturn C-1
1961	Saturn 1 tracking system	Cameras, UDOP and UDOP Beat-Beat, S-band radar, C-band radar, Azusa, Beat-Beat MKII Telemetry, and Telemetry ELSSE	Saturn C-1
1961	Saturn 1 tracking system	S-Band: Prime position data. The C-band was a backup	
1961	Saturn 1 tracking system	Cameras: Early Tracking and position	
1961	Saturn 1 tracking system	ELSSE: (Electronic Skyscreen Equipment) was used "to determine angular deviations of the missile	
9/61	First KSC property acquired	KSC	
10/27/61	First Saturn launch, unmanned	Cape Canaveral	Saturn C-1
2/20/62	John Glenn First US manned Orbital flight Mercury	Cape Canaveral	Atlas

6/12/62	Crawler concept selected	KSC	
Date	Events	Range	Vehicle
11/16/62	New data link	Cape Canaveral, LC-34	Saturn I, SA-3
1962	New data link	First digital data, Pulse code modulated data link, UHF link for higher data rates	Saturn I, SA-3
5/63	Last Mercury mission	Cape Canaveral	Atlas
11/63	President Kennedy Assassinated		
12/63	City and Range renamed after President Kennedy	KSC	
1964	Redesignated Air Force Eastern Test Range (ETR)	Patrick AFB / Cape Canaveral	ELVs: Army-Redstone, Jupiter, Pershing AF: Thor, Atlas, Titan Navy- Polaris
1/29/64	First launch LC-37	Cape Canaveral, LC-37	Saturn I, SA-5
1964	Telemetry: 7 RF links & 1183 measurements 8 onboard cameras	Cape Canaveral	Saturn I, SA-5
2/64	Northern tracks of KSC property acquired	KSC	
1965	Saturn V Program Telemetry: 13 RF links & 1180 measurements	Cape Canaveral	Saturn V
1/23/65	Crawler Operational	KSC LC-39	Saturn V
3/23/65	Gemini III - First manned Gemini mission - Grissom & Young	Cape Canaveral	Titan
6/3/65	Gemini IV - First US EVA - McDivitt & White	Cape Canaveral	Titan
12/65	Gemini VI & VII launch First dual tracking	Patrick AFB / Cape Canaveral	Titan
5/05	17 Ground support stations operational to support Apollo		
2/20/66	First Saturn 1B	KSC LC-34	Saturn 1B
3/66	Gemini VIII - First US docking, first emergency landing - Armstrong & Scott	Cape Canaveral	Titan
5/66	Surveyor lands on moon	Cape Canaveral	Atlas-Centaur
11/66	Gemini XII - Last Gemini mission - Lovell & Aldrin	Cape Canaveral	Titan
1967	NASA builds tracking station on Ascension Island	Ascension Island	
1/27/67	Apollo 1 fire Death of Grissom, White, & Chaffee	Cape Canaveral, LC-34	Saturn 1B
10/9/67	Apollo 4 - First Saturn V launch, First Pad 39 launch	KSC-39A	Saturn V

10/11/68	Apollo 7 - First manned Apollo launch	Cape Canaveral, LC-34	Saturn 1B
Date	Events	Range	Vehicle
12/21/68	Apollo 8 - First Lunar orbit; First manned Apollo/Saturn V launch	KSC-39A	Saturn V
1969	Vehicle has 22 RF links and 3500 measurements	KSC	Saturn V
5/18/69	Apollo 10 - First launch from Pad 39B, Lunar descent	KSC-39B	Saturn V
7/20/69	Apollo 11 First Lunar Landing Man on the moon	KSC-39A	Saturn V
4/11/70	Apollo 13 - Major in-flight problem	KSC-39A	Saturn V
8/9/72	Authority to build Space Shuttle		Space Shuttle
2/22/73	Skylab	KSC-39	Saturn 1B
6/1/75	Grand Turk Island site deactivated	Cape Canaveral	
7/15/75	Apollo-Soyuz	KSC-39	Saturn-1B
1977	Redesignated Air Force Space and Missile Test Center	Patrick AFB / Cape Canaveral	
1979	Redesignated Eastern Space and Missile Center (ESMC)	Patrick AFB / Cape Canaveral	
4/12/81	STS-1 - first launch of RLV \$10,000/lb Shuttle turnaround = 5 mo. Tracking: radar, optics, telemetry	KSC-39	Space Shuttle
1982	Grand Bahamas Island site deactivated	Cape Canaveral	
1982	Tracking ship USNS Arnold retired	Cape Canaveral	
1982	Tracking ship USNS Vandenberg retired	Cape Canaveral	
4/5/83	TDRS - first launch	KSC-39	Space Shuttle
1985	Range Safety & Tracking Turnaround: 48 hrs Tracking: Radar, Optics, Telemetry & Navy FTSS	Eastern Range	Space Shuttle & ELVs
1/28/86	STS-51L Challenger explosion	KSC-39B	Space Shuttle
9/29/88	STS-26 - Shuttle return to service	KSC-39B	Space Shuttle
1990	NASA closes Ascension site	Ascension	
1993	Last Range tracking ship, USNS Redstone, retired	Cape Canaveral	
7/17/95	GPS constellation operational		
1994	Argentia site operational	Eastern Range	
1995	Bermuda site closed	Eastern Range	
1998	Orbit first two pieces of ISS	Russia / KSC-39	Proton / Space Shuttle / ISS
2000	First expedition to ISS	KSC-39	Space Shuttle / ISS
2002	Range Safety & Tracking Turnaround: 48 hrs	Eastern Range	Space Shuttle & ELVs

	Tracking: Radar, Optics, Telemetry & Navy TGRS		
Date	Events	Range	Vehicle
<i>FUTURE</i>			
2010	NASA as customer, 10x cheaper, 100x safer Vehicle turnaround-1 wk, 10 people	Eastern Range & others	2 nd Gen RLV Shuttle replacement (Privately owned)
2025	3rd Gen 100x cheaper, 10,000x safer	Eastern Range & others	3rd Gen RLV
2040	4 th Gen	Eastern Range & others	4th Gen RLV

A.2 COMMUNICATIONS

The following table (Table A-2) timeline covers the introduction to obsolescence period of various types of communications, including wired, wireless, and optical communications systems. In addition, other major historical events and technical milestones along the path of progress, such as data rates of commercial modems, are included as well.

As can be seen scanning through this timeline, the introduction of disruptive communications technology often causes serious turmoil relative to established technology. Yet, in many cases (such as for the 19th Century French optical telegraph based on semaphores mounted on large wooden structures), there are actually periods of multiple decades during which an old technology may co-exist alongside the new, for various reasons.

For instance, the optical telegraph existed for sixty-one years as the primary method of quickly transmitting brief messages across France and Africa, and co-existed for many years with the more modern electric telegraph, due largely to the fact that the optical telegraph was more secure than the wired electric telegraph – the optical telegraph had no wires that could be cut between stations along the network!

On the other hand, there are also instances in which an institution goes out of business within just days of the arrival of a replacing technology, such as for the demise of the Pony Express when the electric telegraph finally spanned the North American continent with the final ‘electrical golden spike’ connection at Salt Lake City, UT. A similar transition is true related to the purchase of Alaska, purchased largely by the insistence of the upper management of Western Union to construct a telegraph line between America and Europe by way of Alaska and Asia. The plans for this telegraph line evaporated almost immediately after the successful invention and installation of higher performance submarine cable that could survive the depths of the Atlantic. In the case of Alaska, though, the mineral wealth and physical beauty are remembered long after the original reason has been relegated to the pages of history.

Historical timelines are valuable to broaden one’s thought process regarding linear time events. They illustrate that progress is never strictly linear, despite the use of timelines, and there are often evolutionary dead-ends along the path of progress, as well as disruptive technology periods, that completely change the time rate of change of progress.

Table A-2 Communications Timeline

Date	Events
350 BC	Free Space Optics communications system of Aeneas for sending alarm signals.
150 BC	Free Space Optics communications system of Polybius. He encoded the 24 letters of the Greek alphabet, in the first recorded optical telegraph.
5/1794	French engineer Claude Chappe, creates a free space optical telegraph and coins the French word “télégraphe” which becomes telegraph in English. His system uses a series of semaphores mounted on towers manned by human operators to relay messages from tower to tower. The network grew to 556 stations spanning 3,000 miles across France, Algeria, and Morocco. A mobile network was built, and used during the Crimean War. Data throughput transfer rate was about 20 to 30 seconds per symbol.
1795	Free space optical telegraph of the British Royal Navy. A shutter technique was used until 1822 when the link was upgraded to a semaphore system to speed signaling rates. Messages could be sent over a 108 km path in about fifteen minutes. System remained in operation until about 1847, when the electric telegraph superseded it
1836-1837	Samuel Finley Breese Morse invents the single-wire electric Telegraph.
1836	Samuel F. B. Morse invents the Relay to solve problem of resistance over long telegraph lines.
1838-1839	Samuel F. B. Morse applies for patents on the Telegraph.
1/24/1838	Samuel F. B. Morse demonstrates his Telegraph over a 10-mile circuit at New York Univ. Data Rate: 10 WPM.
6/20/1840	Morse receives US patent on the Recording Electric Telegraph and on Telegraph Symbols
5/1/1844	First test of 35 km Telegraph line by Morse between Annapolis Junction, MD and Washington, DC.
5/24/1844	"What hath God Wrought" sent from Supreme Court Bldg. in Washington to Baltimore by Morse over Telegraph.
1846	Telegraph operators begin to "sound read" Morse Code in place of reading an inked paper strip.
1849	First teleprinter circuit (New York to Philadelphia) with printed letters instead of Morse symbols.
4/1/1851	Western Union is founded to interconnect different Telegraph Company lines that co-exist.
9/22/1851	Railroad dispatching using telegraphy commences at Turner (now Harriman), NY
1851	First telegraph line across English Channel.
1856	Telegraph Sounder Invented (to permit sound reading of Morse Code)
8/17/1858	First Trans-Atlantic (US - Europe) telegraph cable becomes operational between Trinity Bay, Newfoundland and Valentia, Ireland. It was dubbed the “Eighth Wonder of the World.” First test signals were sent on August 5, 1858. Queen Victoria and President Buchanan exchanged messages on August 16, 1858.
9/18/1858	First Trans-Atlantic telegraph cable fails completely after sending 271 messages between the United States and Europe.
4/3/1860	Pony Express was inaugurated to deliver mail from St. Joseph, MO to Sacramento, CA in only 10 days.
10/21/1861	Western Union connects East Coast telegraph lines with West Coast lines at Salt City, UT
10/24/1861	Disruptive technology supersedes the Pony Express. Pony Express goes bankrupt, ruining investors.
7/26/1866	First successful America to Europe telegraph cable finished by the "Great Eastern", at the time, the world's largest steam ship.. It was the first permanent trans-Atlantic telegraph cable and became operation on July 27, 1866.
8/1866	Disruptive technology of new undersea cable design cancels Western Union's plan for installing a telegraph cable from Alaska to link America and Europe/Asia.
3/27/1867	United States signs treaty to buy Alaska from Russia on urging from Western Union to acquire the land needed for a telegraph cable to Europe. “Seward’s Day”
2/14/1876	Patents filed for Telephone by both Alexander Graham Bell and Elisha Gray.

Date	Events
3/6/1876	First One-way Telephone Call (From Bell to Watson)
3/10/1876	First Two-way Telephone Call (Between Bell and Watson)
1877	First Telephone Exchange Installed (Bridgeport, CT)
10/21/1879	Thomas A. Edison invents light bulb with the thought of providing an optical telegraph without wired lines.
1880	Alexander Graham Bell patents a free space optical telephone system, which he called the Photophone. The experimental Photophone was donated to the Smithsonian Institution, where it literally languished on the shelf for over half a century before light was once again used to transmit voice
1883	First Networked Telephone System (Between Boston and New York)
1888	Heinrich Hertz discovers Radio Waves.
8/13/1889	Coin Operated Telephone Patented.
3/11/1891	Almon Strowger of Kansas City Patents First Automatic Telephone Exchange
5/10/1894	Guglielmo Marconi sends a radio wave for 3/4 mile, inventing Wireless communication.
6/2/1896	Marconi receives Wireless apparatus patent from Britain.
12/23/1900	Reginald Aubrey Fessenden invents Wireless Telephony (Radio), transmitting voice for the first time.
12/12/1901	First Trans-Atlantic Wireless communication. Marconi receives an "S" at St. John's, Newfoundland sent from Poldhu, Cornwall, England using Wireless apparatus at 12:30 PM Newfoundland time.
1/18/1903	Marconi demonstrates first Trans-Atlantic two-way Wireless communication.
12/24/1906	Fessenden broadcasts voice and music over radio for the first time, surprising radio operators aboard ships at sea.
1915	First wireless radio call across the Pacific Ocean.
10/27/1920	KDKA in Pittsburgh, PA receives license to commence broadcasting one-hour 8:30 PM to 9:30 PM news broadcasts as first commercial Radio station. Later expands to music, news, and sports.
1921	First one-way wireless voice paging receiving equipment installed in police cars. (Detroit, MI. Callsign: KOP)
5/18/1923	Antoine Barnay of France files patent application for first rotary telephone
1924	First Mobile two-way Telephone System (New York City Police Cars)
6/19/1934	Communications Act of 1934 establishes Federal Communications Commission. (Public Law No. 416, June 19, 1934, 73rd Congress)
1934	Half of US homes have radio receivers.
1946	First Commercial Mobile Telephone System (St. Louis, MO)
1949	Western Union relinquishes all rights of ownership to telegraphy equipment installed alongside railroads. Most commercial "sound read" telegraphy by humans ceases.
1958	Schawlow and Townes at Bell Telephone Laboratories file for a patent on the laser
1960	Theodore Maiman builds the first working laser at Hughes Aircraft Company.
1960	300 Baud commercial modem speeds first achieved.
1960	The Schawlow and Townes patent on the laser, filed in 1958, is granted to Bell Telephone Laboratories.
4/17/1964	IBM announces System/360 computer.
11/1964	Bell Telephone Laboratories joins the MULTICS project with MIT and GE.
10/1965	First Networked Computer Experiment at MIT Lincoln Lab – two computers talk to each other using packet-switching technology.
1965	MULTICS started
1967	First cordless phones introduced.
12/1968	ARPANet contract given to Bolt, Beranek & Newman (BBN) in Cambridge, MA. The output will

	become, in time, the Internet.
Date	Events
4/1969	Bell Telephone Laboratories pulls out of the MULTICS project that had started as a joint venture of MIT, General Electric, and Bell Labs due to cost over-runs, and severe disagreements on what MULTICS should be. The original computer targeted was a GE-645 MULTICS machine.
1969	UNIX (intended as a pun on MULTICS) first runs on a PDP-7 at Bell Telephone Laboratories, written in PDP-7 assembler. The PDP-7 provides 8K 18-bit words of memory. The ultimate goal is to re-write UNIX in a high-level language, and make UNIX be everything MULTICS was not.
5/1970	Honeywell buys GE Computer division, thereby taking over MULTICS.
7/1970	Alohanet, first packet radio network, operation at University of Hawaii. Pioneering ideas contained in this network will form the basis of Ethernet.
9/1970	Low-loss fiber optic cable manufacturing techniques announced by Robert Maurer, Donald Keck and Peter Schultz of Corning Glass Works (now Corning, Inc.). They achieve a loss-limit of 20 dB/km, or less for optical fiber.
3/1972	Invention of e-mail. First e-mail programs written by Ray Tomlinson at BBN for ARPANET: SNDMSG and READMAIL. "@" Sign chosen for its "at" meaning in addressing, instead of the ampersand (which was a Latin shorthand symbol for "and").
1972	Ethernet is invented by Robert M. Metcalfe, David R. Boggs, Charles P. Thacker, and Butler W. Lampson to interconnect the Xerox Alto, a personal workstation, with other Altos, and to servers and shared printers
1971-1973	High-level programming language known as "C" is created at Bell Laboratories. UNIX (based on everything that MULTICS was not) is simultaneously ported to C, and support for networking is built into UNIX.
4/1973	First phone call on a portable cell phone. (Call made by Dr. Martin Cooper of Motorola to his rival, Joel Engel, Bell Labs' head of research.)
1975	Robert M. Metcalfe, David R. Boggs, Charles P. Thacker, and Butler W. Lampson file patent application for Ethernet.
1976	Apple Computer, founded by Steve Jobs and Steve Wozniak, produces the Apple I in Job's parents' garage. The Apple I features a wooden frame, and appeals mostly to computer hobbyists.
1977	Apple Computer introduces a more advanced computer known as the Apple II. This product launches the Personal Computer (PC) Industry. (See May 2002, MILA.)
12/13/1977	Xerox Corporation (Robert M. Metcalfe, David R. Boggs, Charles P. Thacker, and Butler W. Lampson) receive patent for Ethernet. (US Patent 4,063,220).
1977-1978	AT&T Bell Labs starts public trial testing of a Mobile Phone System based on hexagonal regions (cells) in Chicago, IL.
1979	VisiCalc debuts, providing the first spreadsheet software, and becomes the killer-application that kick-starts the Apple II PC and PCs in general, providing a long-awaited business reason to buy a PC.
1979	Bob Metcalfe founds 3COM (short for C omputer, C ommunication, and C ompatibility)
7/1980	IBM meets with Microsoft's Bill Gates for the first time to discuss buying an operating system for a hush-hush "personal" computer to be designed and built in Boca Raton, FL, on a computer codenamed "Acorn", as part of a project codenamed "Project Chess".
8/12/1981	IBM introduces the IBM Personal Computer (PC), providing big-business creditability to the infant PC industry. The processor (an 8088) runs at 4.77 MHz and is equipped with 16 kilobytes of memory. The PC comes with one or two 160-kilobyte drives, and is priced starting at \$1,565.
8/1981	The VisiCalc software by Software Arts Incorporated is ported to the IBM PC. A killer-application that launched the PC software industry. (The original DOS 1.0 software of 27,520 bytes from 1981 is archived on the Internet at http://www.bricklin.com/history/vcexecutable.htm and still runs on modern PCs. This software is freely available for use for historical research purposes. Lotus now owns the rights. It only runs in the current directory, as sub-directories had not yet been created in DOS 1.0.)
1983	Cell phones commence nationwide operation in the United States

Date	Events
1984	William Gibson's novel, <i>Neuromancer</i> , provides the first vision of a globally interconnected network of computers. Gibson coins the word "cyberspace".
11/1985	Microsoft releases Windows 1.0, originally known as the Interface Manager, to compete with the Apple Macintosh. It fails miserably in the marketplace.
1987	56 kb/s commercial modem speeds first achieved.
11/1987	Microsoft releases Windows 2.0, to compete with the Apple Macintosh. This is the first version of Windows to feature icons, long a staple of the Macintosh screen. In spite of finally using icons, Windows 2.0 fails miserably in the marketplace.
11/1987	Bull buys the Honeywell Computer Division, thereby taking over MULTICS.
11/2/1988	First Internet worm created and let loose by a 23 year-old graduate student named Robert Tappan Morris at Cornell University. The Morris Worm was a 99-line program (not including object files) that completely paralyzed the entire Internet, as well as many intranets within companies that had connectivity to the Internet.
1989	McAfee Associates is founded to combat computer virus attacks. Anti-virus software is made available free.
5/1990	Microsoft releases Windows 3.0, in what is a serious overhaul of Windows code from Windows 2.0, but there are still fatal shortcomings such as lack of network support, and no easy way by which to share data between multiple applications running at the same time. (Three strikes, but Microsoft does not strike 'out'.)
4/1992	On its fourth attempt, Microsoft finally succeeds in a Windows software package. Microsoft releases Windows 3.1 (WIN3.1) and it becomes the first widely accepted graphical user interface for DOS-based (DOS: disk operating system) personal computers. Although there are serious shortcomings relative to the Macintosh operating system, WIN3.1 does finally provide network support, as well as TrueType fonts, functional yet rudimentary multi-media support, and OLE (object linking and embedding). With OLE, it finally becomes possible to share data between multiple applications running at the same time on a PC. Windows software finally starts to move off vendors' shelves. Win3.1 runs only on the latest 80286 or 80385 processors with at least 1 Mb of memory, instantly obsolescing all of the XT and earlier PCs.
1993	Fast Ethernet Alliance (FEA), comprised of a group of vendors, is formed to standardize the requirements for a faster Ethernet to achieve 100 Mb/s in place of 10 Mb/s data transfer rates.
1993	Mosaic Web Browser (known as Mozilla) is created at the University of Illinois as part of NCSA free software by Marc Andreessen. Available for free distribution via ftp (file transfer protocol) over the Internet.
7/1993	Microsoft releases Windows NT. Windows finally supports longer, descriptive file names, with names longer than 8 bytes, as supported on UNIX since the 1970's and on the Macintosh since January 1984.
4/1994	Marc Andreessen founds Netscape Communications to commercialize the Mozilla web browser, and immediately captures nearly 100% of the web browser market.
12/1994	Microsoft licenses Web browser technology from Spyglass to create an Internet Explorer (i.e., a web browser) for the planned Windows 95.
8/24/1995	Microsoft releases the second widely accepted graphical user interface for DOS (disk operating system) personal computers (PCs) in a software product known as Windows 95. Product closely matches the look and feel of Apple Computer's Macintosh operating system that debuted nearly 12 years earlier on January 24, 1984.
1995	"Apple reports a larger-than-expected 48 percent drop in fourth-quarter profits, to \$60 million, despite a 20 percent rise in sales to a record \$3 billion." --Reuters
9/1996	4 Mb/s Cable Modem commercial modem speeds first achieved.
2/1997	10 Mb/s Cable Modem commercial modem speeds first achieved.

6/1997	8 Mb/s ADSL commercial modem speeds first achieved.
Date	Events
3/1998	DOCSIS cable modem specification is approved by ITU. DOCSIS defines downstream data transfer rates of 27 to 36 Mb/s over frequencies from 50 MHz to 750+ MHz and upstream data transfer rates of 320 Kb/s to 10 Mb/s from 5 to 42 MHz. Within nine months (by the end of 1998) there would be 1.2 Million cable modems installed within homes in the United States, providing the first widespread broadband Internet connectivity to the home. Market forecasts predict 24.3 Million cable modems will be installed in US homes by 2004.
4/24/1998	LightPointe Communications of San Diego, CA files the primary patent for Free Space Optics using EDFAs (Erbium Doped Fiber Amplifiers) to increase receive sensitivity.
2/1/1999	Wireless Morse Code (CW) aboard ships is phased out, to be replaced by Satellite Communications.
5/1999	Shawn Fanning, a freshman at Northeastern University, starts the Napster online music service. The service, providing peer-to-peer file sharing arranged through a central server, allows users easily to trade music encoded in the MP3 format, which compresses recordings into small and portable files without sacrificing much quality.
6/16/1999	Diamond Multimedia wins its case before the 9th U.S. Circuit Court of Appeals that its portable MP3 player does not violate the Audio Home Recording Act of 1992 that prohibits devices that make copies from digital music recordings. The court ruled that Diamond Multimedia's Rio player made copies from computer hard-drives, and did not copy digital music recordings. Portable MP3 players from Diamond Multimedia immediately become available in retail stores, fueling demand for MP3 files from online service Napster. Internet traffic starts to double every ninety days, as music lovers start obtaining MP3 recordings for their portable MP3 players and computers.
8/1999	The Wireless Ethernet Compatibility Alliance (WECA) is formed with just six member companies to certify interoperability of Wi-Fi (IEEE 802.11) products and to promote Wi-Fi as the global wireless LAN standard across all market segments.
12/1999	Multiple companies file lawsuits to shut down Napster, to prevent peer-to-peer sharing of MP3 files. Internet traffic continues to double every 90 days.
5/10/2000	FCC issues an NPRM (Notice of Proposed Rulemaking) to solicit comments on permitting Part 15 Ultra Wideband (UWB) transmissions.
7/26/2000	U.S. Judge Marilyn Hall Patel issues an injunction against Napster, prohibiting copyrighted songs from appearing on its online file-sharing service, while lawsuits proceed through the court system. Internet traffic spikes, as MP3 aficionados attempt to complete their MP3 music collections.
7/28/2000	Napster appeals Judge Patel's injunction to the 9th U.S. Circuit Court of Appeals, which stays Judge Patel's order on July 28, allowing Napster to continue operations until the case goes to trial. Internet traffic drops back down to a high growth rate of still doubling every 90 days.
10/30/2000	Last MULTICS computer is decommissioned, effectively ending a computer and computer operating system project that started in 1965. UNIX machines now dominate Internet-connected computer mainframes throughout the world.
2/12/2001	9th Circuit Court of Appeals rules Napster users are illegally copying and distributing copyrighted commercial songs and orders Napster to stop its users from trading and distributing copyrighted material. The ruling allows Napster to continue operating until Judge Patel's injunction is modified to comply with the appeal court's decision. Internet traffic again spikes, but starts to decline within days as song titles become harder to find, with attempts to eliminate copyrighted songs implemented by Napster to comply with the 9 th Circuit Court of Appeals rules.
5/2/2001	Technology research firm Webnoize reports the number of songs swapped on Napster was down 36 percent between March and April 2001. It is estimated that nearly 1.6 billion MP3 files changed hands in March. Average song length is approximately 4 MB. Internet traffic starts to decline simultaneously, precipitating an immediate increase in order cancellations for telecom equipment from system providers.
5/29/2001	LightPointe Communications of San Diego, CA receives the primary patent for Free Space Optics using EDFAs filed on April 24, 1998.

Date	Events
7/2/2001	Judge Patel orders Napster offline until it proves it is 100% free of copyrighted works. Napster goes completely 'off the air.' Internet traffic stops growing, and even starts to drop in volume. Additional order cancellations are placed within days by system providers for telecom gear intended for the Internet backbone.
9/2001	The Wireless Ethernet Compatibility Alliance (WECA) is now comprised of over 130 member companies, and declares 200 certified Wi-Fi devices.
11/30/2001	European Space Agency (ESA) Artemis satellite launched 12 July 2001 from the European launch base in Kourou, French Guiana aboard an Ariane 5 launch uses a laser-based Silex Communication system to transmit 50 Mb/s to a SPOT 4 satellite in the first-ever publicly announced satellite-to-satellite laser-communication link demonstration.
2/14/2002	FCC adopts a First Report and Order (FCC 02-48) permitting Part 15 Ultra Wideband (UWB) transmissions under limited circumstances.
5/2002	The MILA (Merritt Island Launch Annex) continues to use Apple IIe computers to provide mission-critical shuttle communications during launch and landings at Kennedy Space Center. Press coverage identifies that NASA cruises Ebay and other on-line Internet auction sites to obtain spare parts for obsolete computer systems. (The Apple II computer line was launched in 1977, and created the Personal Computer industry.)
6/3/2002	Napster files for Chapter 11 bankruptcy as part of an overall financial restructuring strategy of Bertelsmann AG to clear the books of debt. Bertelsmann AG proceeds with its takeover of Napster. Future is unclear whether Napster will ever recover the 50 Million users it once had, especially as Bertelsmann AG plans a subscription service in place of the formerly free service.

B. LAUNCH CENTERS & RANGES

B.1 EASTERN RANGE

B.1.1 Background

B.1.1.1 General

The Eastern Range (ER), headquartered at Patrick Air Force Base (PAFB), Florida, is used for eastwardly launches in support of the following types of military, government and civilian missions:

- Manned missions
- Orbital
- Suborbital
- Inter-planetary
- Ballistic Missiles

The Eastern Range is operated by the 45th Space Wing (SW). Since its beginning in 1949, the Eastern Range has been the premier U.S. missile and space support range. Currently, it is the only US launch facility equipped to support manned space flight. The Eastern Range, with its eastwardly launches; and the Western Range, with westward and polar launches; together support almost 100% of US space launches (Figure B.1-1).



Figure B.1-1 Eastern & Western Ranges

The area covered by the Eastern Range spans more than 5000 miles. Range facilities extend southeast to Ascension Island in the south Atlantic and northeast to Argentina, Newfoundland. Launches are from Cape Canaveral Air Station (CCAS) on the Atlantic Coast of Florida at approximately 28.5N, 80.6W. One advantage of the range is the proximity to the equator to launch vehicles in Geosynchronous Earth Orbit (GEO). Orbital launches from the ER are limited to azimuths between 37 and 112 degrees. Another advantage is over-water flight trajectories that make long-range missile flights possible over an area relatively free of shipping lanes and inhabited landmasses.

The Eastern Range is comprised of multiple operational locations (Figure B.1-2). Depending on the launch vehicle and direction, any or all of these locations may be utilized. The Eastern Range locations and the dates they became operational are as follows:

- Patrick AFB -1940
- CCAS -1950
- KSC - 1960
- JDMTA - 1985
- Antigua - 1957
- Ascension - 1957
- Argentinia - 1993

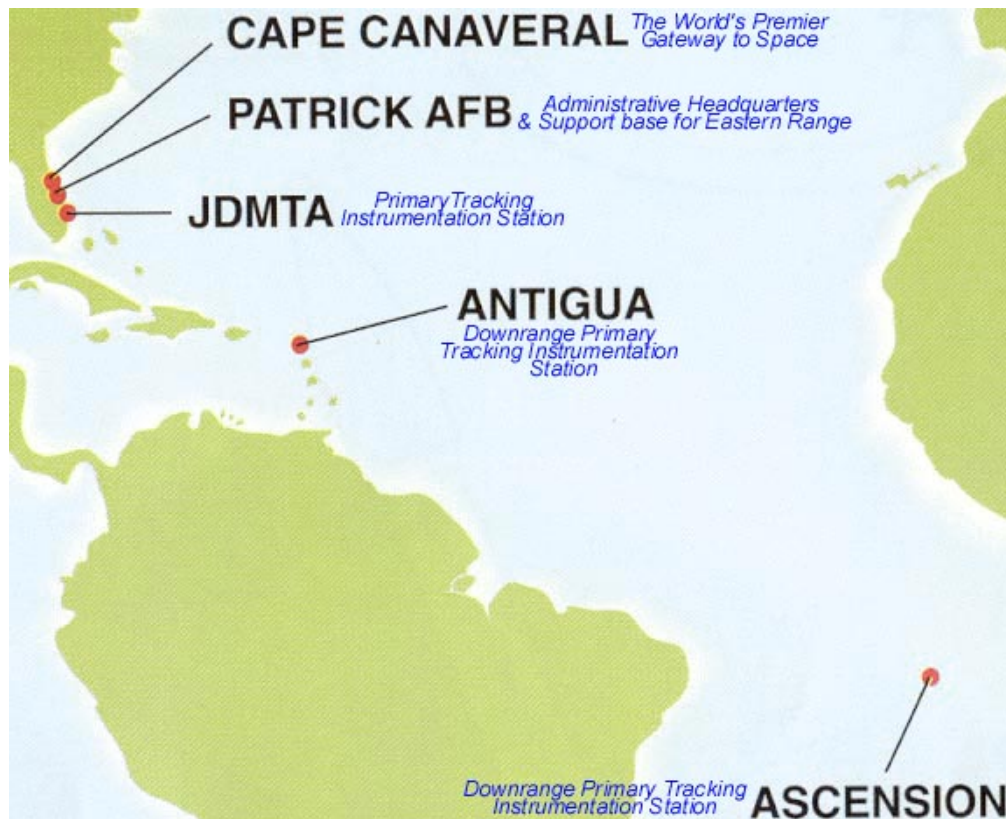


Figure B.1-2 Locations of Eastern Range Facilities

NASA's Kennedy Space Center (KSC) is a separate entity from the Eastern Range. KSC contains its own launch facilities and Launch Operations Control Center. KSC is located directly adjacent to the Cape Canaveral Air Station. The Eastern Range's Telemetry station (TEL-4) is physically located on the KSC property. NASA utilizes the Eastern Range assets for its launches. KSC will be discussed briefly in this section and in more detail under the KSC section.

B.1.1.2 History

As discussed at length previously, in May 1947, a V-2 launched from White Sands went awry. This incident led to the decision to find a new launch location. Candidate locations included the following³³⁹:

- Northern Washington State with a range along the Aleutian Islands
- El Centro, California with a range down the coast of Baja California
- Banana River Naval Air Station with launching sites at Cape Canaveral and a range over the Bahamas

The California site was the Government's first choice, with Cape Canaveral as second. The California site was later abandoned after Mexico refused to allow missile flights over Baja California. Cape Canaveral was then chosen since the British were willing to allow missile flights near the Bahamas and further agreed to lease land for the down range stations.

The Eastern Range began in 1949 when the newly organized Air Force Division of the Joint Long Range Proving Ground assumed responsibility for the Joint Long Range Proving Ground Base³⁴⁰. This base had been called the Banana River Naval Air Station.

The Banana River Naval Air Station was a World War II seaplane patrol and training base. Work began on the site in December 1939, and the station was commissioned on 1 October 1940. The station supported seaplane patrol operations during World War II. It was briefly deactivated after World War II.

The Long Range Proving Ground Base was renamed Patrick Air Force Base in honor of Major General Mason M. Patrick on 1 August 1950. General Patrick had been Chief of the American Expeditionary Forces Air Services in World War I and Chief of the Air Service/U.S. Army Air Corps. The Eastern Range was also renamed multiple times over the years. It has previously been called:

- ESMC – Eastern Space and Missile Center
- ETR – Eastern Test Range

³³⁹ <https://www.patrick.af.mil/heritage/45thHist/EVWing.htm>

³⁴⁰ <https://www.patrick.af.mil/heritage/45thHist/Preface.htm>

Air Force personnel operated tracking systems on the Eastern Range up through December 1953. Cost comparison studies undertaken two years earlier had shown the desirability of letting contractors operate the Cape and the downrange stations. On December 13, 1953, the first range contract was signed with Pan American World Services. Pan American signed a contract with RCA to make the latter responsible for operating and maintaining range stations and tracking systems. This team operated the Eastern Range for over thirty years until CSR won the Range Technical Services (RTS) contract in 1988. In 2000, the Engineering side of the Technical Services contract was separated from Operations and Maintenance. CSR won the new Range Technical Service Contract (RTSC) effective 1 April 2000. On 3 November 2000, the Space and Missile Systems Center (SMC) awarded the Space Lift Range System Contract (SLRSC) to ITT Industries³⁴¹.

Primarily to accommodate testing requirements for winged missiles like the SNARK and NAVAHO, in October 1952, plans were approved to extend the Eastern Range's length to 5,000 miles. These were basically long-range cruise missiles. The Eastern Range supported its first 5,000-mile-long mission (a SNARK test flight) on October 31, 1957. To achieve the extended range, additional support sites were added.

Throughout its history, the ER has included numerous supporting sites. Presently sites are maintained at JDMTA, Antigua, Ascension, and Argentina. By January 1960, the Eastern Range included 13 major stations, approximately 91 outlying sites, a fleet of ships and three marine support stations (Figure B.1-3). By September 1963, the Eastern Range extended around the tip of South Africa to the island of Mahe in the Indian Ocean. Major sites and their dates of operation include the following³⁴²:

- Valkaria, Fl – [1961-]
- Jupiter, Fl – [1954-1985] (Near present day JDMTA)
- Grand Bahamas Island, Bahamas – [1954-1987]
- Carter Cay, Bahamas – [1961-]
- Eleuthera, Bahamas – [1955-1971]
- San Salvador, Bahamas – [1955-1965]
- Mayaguana – [1955-1970]
- Grand Turk – [1955-1982]
- Mayaguez, Puerto Rico – [1956-1961]
- East Island – [1961-1963]
- Dominican Republic – [1956-1962]
- St. Lucia, Brazil – [1956-1967]
- Fernando de Noronha (off Brazil) – [1958-1969]
- Pretoria, South Africa – [1961 -1967]

³⁴¹ <https://www.patrick.af.mil/heritage/45thHist/CONTRACT.htm>

³⁴² <https://www.patrick.af.mil/heritage/45thHist/DER.htm>

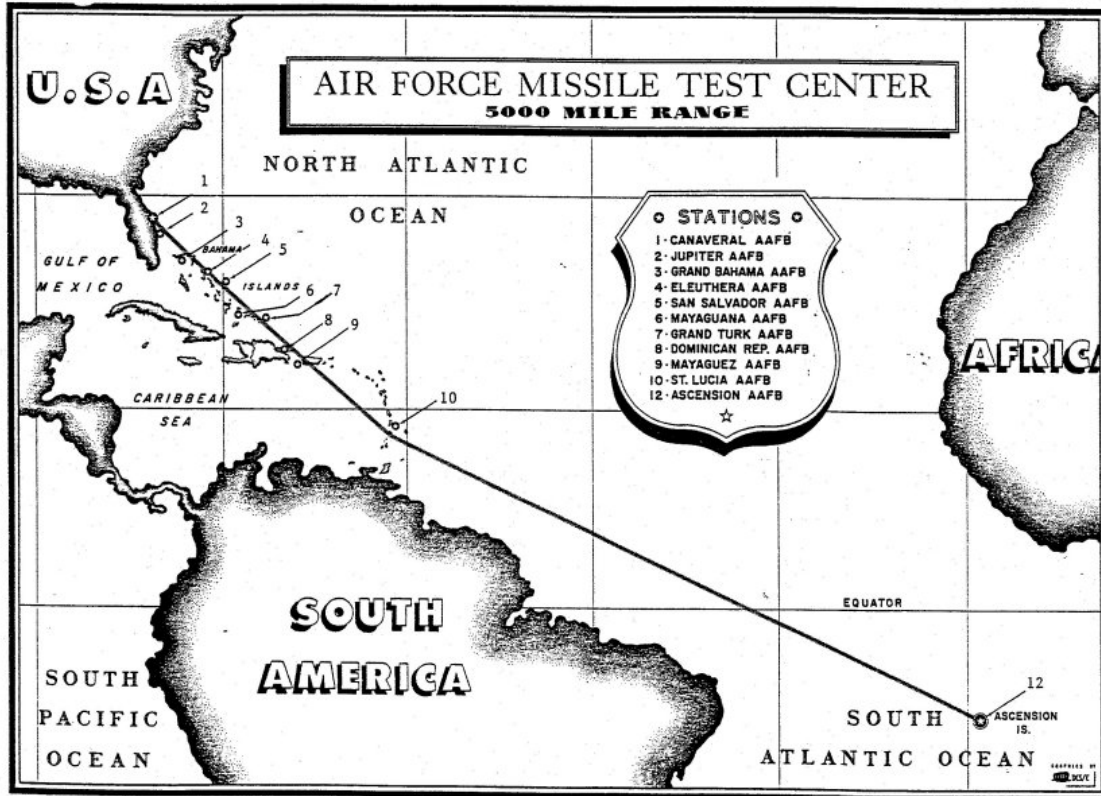


Figure B.1-3 Eastern Range In Early 60's

In addition, range instrumentation ships were used to fill in those areas not covered by land bases. The range ships and their dates of operation are as follows³⁴³:

- USNS Range Tracker (T-AGM 1) 1961-69
- USNS Range Recoverer (T-AGM 2) 1960-72
- USNS Longview (T-AGM 3) 1960-74
- USNS Richfield (T-AGM 4) 1960-70
- USNS Sunnyvale (T-AGM 5) 1960-74
- USNS Watertown (T-AGM 6) 1961-72
- USNS Huntsville (T-AGM 7) 1961-71
- USNS Wheeling (T-AGM 8) 1962-79
- USNS General H. H. Arnold (T-AGM 9) 1964-82
- USNS Gen. Hoyt S. Vandenberg (T-AGM 10) 1964-83 (Used in 1997 movie Virus³⁴⁴)
- USNS Twin Falls (T-AGM 11) 1964-68
- USNS American Mariner (T-AGM 12) 1964-66
- USNS Sword Knot (T-AGM 13) 1964-71

³⁴³ <http://www.usmm.org/msts/specialships.html>

³⁴⁴ http://www.bigshipwrecks.com/history/universal/filming_for_universal_studios.htm

- USNS Rose Knot (T-AGM 14) 1964-68
- USNS Coastal Sentry (T-AGM 15) 1964-71
- USNS Coastal Crusader (T-AGM 16) 1964-76 (Redesignated T-AGS 36 in 1969)
- USNS Timber Hitch (T-AGM 17) 1964-68
- USNS Sampan Hitch (T-AGM 18) 1964-68
- USNS Vanguard (T-AGM 19) 1966-98 (Redesignated T-AG 194 in 1980)
- USNS Redstone (T-AGM 20) 1966-93
- USNS Mercury (T-AGM 21) 1965-76
- USNS Range Sentinel (T-AGM 22) 1971-97
- USNS Observation Island (T-AGM 23) 1979-Present

Of these 23 ships, the last tracking ship for the Eastern Range was the Redstone (Figure B.1-4), which was decommissioned in 1993. The Range Sentinel continued to support Eastern Range activities until 1997, but it was primarily for Navy launches only. Today, only the Observation Island (Figure B.1-5) is still in operation. It usually stays in the Pacific and almost never supports Eastern Range activities.



Figure B.1-4 USNS Redstone



Figure B.1-5 USNS Observation Island

After 1957, ballistic missile and space programs quickly came to dominate the Eastern Range³⁴⁵. The MATADOR, BOMARC, SNARK and NAVAHO were eclipsed by the Army's JUPITER, the Navy's POLARIS and the Air Force's THOR, ATLAS, TITAN and MINUTEMAN ballistic missile programs. The Army REDSTONE and the Air Force ATLAS were also adapted to support NASA's MERCURY manned space program in the early 1960s.

B.1.2 Facilities

The Eastern Range has major facilities at the following locations

Patrick AFB	Headquarters, Radar, Optics, Test Beds
CCAS	Launch Complexes (LC), Radar, Optics, Command Destruct, Control, Weather
KSC	Telemetry
JDMTA	Radar, Telemetry, Command Destruct
Antigua	Radar, Telemetry, Command Destruct
Ascension	Radar, Telemetry
Argentina	Radar, Telemetry, Command Destruct

In addition, facilities at NASA's Wallops Island and the Air Force Satellite Control Network's (AFSCN) site in New Hampshire are also used for northern trajectories.

³⁴⁵ <https://www.patrick.af.mil/heritage/45thHist/DER.htm>

B.1.2.1 Patrick AFB**Background**

Patrick AFB (Figures B.1-6 & B.1-7) is located on the east central coast of Florida, about 69 miles east of Orlando. The base, covering 2,108 acres, is situated between the Banana River and the Atlantic Ocean. Sitting nine feet above sea level, the base extends over an area 4.1 miles from north to south, and 1.25 miles from east to west³⁴⁶.



Figure B.1-6 Patrick AFB Entrance

³⁴⁶ <http://www.computersciencesraytheon.com/home.html>



Figure B.1-7 Patrick AFB (Satellite Image)

PAFB is headquarters for the Eastern Range. It contains the 45 SW headquarters, range engineering, shop facilities, test facilities, a radar-tracking site and an optics-tracking site. Being an Air Force base, Patrick also includes: security, hospital, food services, commissary, housing, hangars, air terminal, runways, aircraft maintenance facilities, and recreation facilities. The Patrick terminal is used for weekly downrange flights to Antigua and Ascension.

Patrick is also host facility to other organizations including:

- Air Force Technical Application Center (AFTAC) – SALT treaty verification
- Department of State/Air Wing (DOS/AW) – aircraft refurbishing
- Cobra Judy Project – USNS Observation Island (Figure B.1-5)
- Joint Stars Joint Test Force (J-STARS) – Airborne radar
- Defense Equal Opportunity Management Institute (DEOMI)³⁴⁷ - Training
- Defense Reutilization & Marketing Office (DRMO) – Excess materials disposal

³⁴⁷ <https://www.patrick.af.mil/tenants/index.htm>

Instrumentation

Patrick AFB includes the following Range systems:

- Radar (0.14)
- Optics (PIGOR)
- Weather radar

In addition, Patrick AFB includes the following test beds:

- Radar
- Telemetry
- Antenna Range

B.1.2.2 CCAS

Background

Cape Canaveral Air Station (CCAS) [Figure B.1-8] is located 21 miles north of Patrick Air Force Base, and serves as the Eastern Range space processing and launch area. The 45th Space Wing provides spacecraft processing, launch and tracking facilities, safety procedures, and test data to a wide variety of customers and also manages launch operations for DoD space programs.

Cape Canaveral facilities include launch complexes, booster and payload assembly buildings, computer centers, Range control center, communication hubs, and other elements essential to the assembly, pre-launch, launch, and post-launch operations of space and ballistic vehicles. Cape Canaveral also includes port facilities for submarines and surface ships.

Cape facilities include the following:

Hangar AE – Hangar AE is a NASA facility used for pre-launch preparations and check out of unmanned payloads. The building consists of a high bay clean room complex, a telemetry ground station, the Mission Director's Center (MDC), and offices for payload management and contractor personnel. The KSC NASA Payload Management and Operations Directorate use this building as their "communications center"³⁴⁸.

³⁴⁸http://216.239.33.100/search?q=cache:uGgy5TG_nhkC:www.ksc.nasa.gov/elv/eastern.htm+&hl=en&ie=UTF-8

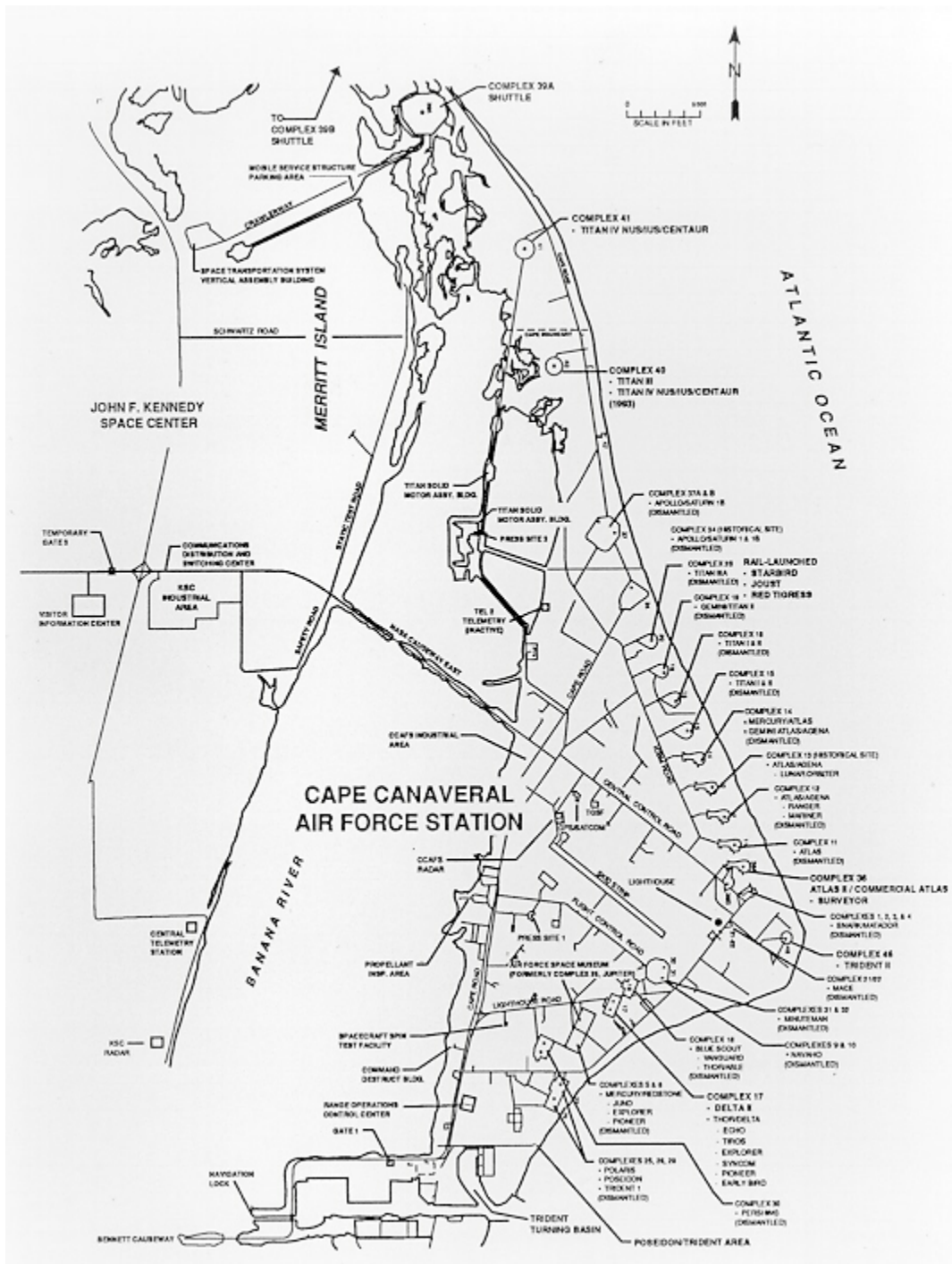


Figure B.1-8 Cape Canaveral Air Station (CCAS)

Hangar AF – Hangar AF is a NASA facility used for processing and refurbishing the Solid booster Rockets.

ROCC - The Range Operations Control Center (Figure B.1-9) complex provides flight safety, weather, scheduling, launch control and instrumentation target designation support in real time for each missile and space launch.



Figure B.1-9 Range Operations & Control Center (ROCC)

Skid Strip – CCAS has a 10,000-foot landing strip, which is used for delivery and support of missile and payload components. It gets its name from its earlier use in support of winged air breathing missile tests where the vehicles were flown downrange and then commanded to turn around and return to the Cape for a skid recovery.

NOTU – The Naval Ordnance Test Unit supports Navy activities at the Eastern Range. They have multiple facilities at the Cape.

Poseidon Wharf – This port facility is used for berthing various ships and for loading the transports for downrange shipping to Antigua and Ascension (left basin in Figure B.1-10).

Trident Basin – This larger port area supports Trident test submarines and some visiting surface ships. It contains submarine support and missile loading capabilities (right basin in Figure B.1-10).

AF Space Museum – This facility at the site of the first Cape manned launch contains a collection of past launch vehicles and an early launch blockhouse (Figure B.1-11).

Light House – The Cape area contains an historic lighthouse (Figure B.1-12) that was rebuilt in 1868 and moved to its present location in 1894³⁴⁹.

³⁴⁹ <http://users.erols.com/lthouse/cclt.htm>



Figure B.1-10 **Poseidon Warf & Trident Basin**



Figure B.1-11 **AF Space Museum**



Figure B.1-12 Cape Canaveral Light House

Launches - Cape Canaveral, with adjacent KSC, has approximately 50 launch complexes (Figures B.1-13 and B.1-14) numbered LC-1 through LC-47. Currently, many of these are not in use. A few are listed as National Historic sites. Some of the complexes contain multiple pads (i.e. 39A and 39B). A brief summary of launch complexes is provided in Table B.1-1³⁵⁰.



Figure B.1-13 Cape Launch Complexes in 1960's

³⁵⁰ <https://www.patrick.af.mil/heritage/LaFacility/Launchframeset.htm>



Figure B.1-14 Cape Launch Complexes in 1990's

Table B.1-1 Communications Timeline

LC	Act.	Vehicle	Capsule	Yrs in Use	Comments
1		SNARK MATADOR Aerostat		1953-1960 1983-1989	
2		SNARK MATADOR Aerostat		1953-1960 1983-1989	
3		BUMPER BOMARC JACON Redstone X-17 Polaris Aerostat		 1950-1960 1983-1989	1 st Cape launch 7/24/50
4		BUMPER BOMARC JACON Redstone X-17 Polaris Aerostat		 1950-1960 1983-1989	
5		Jupiter -		1955-1964 1964-present	AF Space Museum

LC	Act.	Vehicle	Capsule	Yrs in Use	Comments
6		Redstone -	Mercury	1955-1964 1964-present	1 st manned flight 5/5/1961 AF Space Museum
7					
8					
9		Navaho		1956-1959	Demolished 1959 for LC 31 & 32
10		Navaho		1956-1959	Demolished 1959 for LC 31 & 32
11		Atlas		1957-1967	
12		Atlas/Agena Ranger Mariner		1957-1967	
13		Atlas Atlas/Agena		1957-1978	
14		Atlas	Mercury Gemini	1957-1967	1 st Orbital flight 2/20/1962
15		Titan I & II		1959-1967	
16		Titan I & II NASA tests Pershing 1A & II		1959-1965 1965-1967 1972-1988	
17A	Y	Thor Delta NASA tests Delta II		1956-1960 1960-1965 1965-1988 1988-present	NASA
17B	Y	Thor Delta NASA tests Delta II Delta III		1956-1960 1960-1965 1965-1988 1988-1997 1997-present	NASA
18A		Vanguard Blue Scout		1956-1960 1960-1967	
18B		Thor Blue Scout I, II		1956-1961 1961-1967	
19		Titan I Titan II	Gemini	1959-1967 1962-1967	
20	Y	Titan I Titan III Commercial		1959-1964 1964-1967 1999-present	Red Tigriss Spaceport Fla
21		Blue Goose Mace		1957-1958 1959-1970	
22		Blue Goose Mace		1957-1958 1959-1970	
23					
24					
25A		Polaris		1957-1969	
25B		Polaris		1957-1969	
25C		Poseidon Trident I		1967-1977 1977-1979	
25D		Poseidon		1967-1979	
26		Redstone Jupiter Juno -		1956-1964 1964-present	AF Space Museum

LC	Act.	Vehicle	Capsule	Yrs in Use	Comments
27					
28					
29A		Polaris Chevaline		1959-1968 1977-1980	British
29B		Polaris		1959-1968	
30A		Pershing		1960-1968	
30B		Pershing		1960-1968	
31A		Minuteman Pershing 1A		1960-1973 1973	Pad
31B		Minuteman		1960-1973	Silo Challenger burial
32A		Minuteman		1960-1964	Pad
32B		Minuteman Minuteman II Minuteman 3		1960-1964 1964-1968 1968-?	Silo Challenger burial site
33					
34		Saturn I & IB	Apollo	1963-1971	Apollo 1 fire
35					
36A	Y	Atlas/Centaur Atlas II		1961-1989 1989-present	NASA AF
36B	Y	Atlas/Centaur Atlas II Atlas III		1964-1989 1989-2000 2000-present	NASA AF AF
37A	Y	Saturn I & IB Delta IV	Apollo	1963-1971 2002-present	1 st unmanned lunar EELV first flight in 2002
37B		Saturn I & IB	Apollo	1963-1971	
38					
39A	Y	Saturn V Shuttle	Apollo	1965-1981 1981-present	On KSC 1 st Shuttle 4/12/1981
39B	Y	Saturn V Saturn IB Shuttle	Apollo Apollo	1966-1973 1973-1981 1981-present	On KSC Skylab & Soyuz
40	Y	Titan III Titan IV		1965-1994 1994-present	
41	Y	Titan III Titan IV Atlas V		1965-1977 1988-1999 2002-present	Mars Viking 1975 & Voyager 1977 EELV first flight in 2002
42					
43		Sounding		1962-1984	
44					
45		Roland		1975-1976	No launches
46	Y	Trident II Commercial		1986-1995 1997-present	Spaceport Florida & Future Trident
47	Y	Sounding Loft Super Loki		1984-present 1984 1992	Student rocket

Instrumentation

CCAS has the following types of instrumentation:

- Radar (1.39, 1.8, 1.16, SPARC, MOTR)
- Optics (ATOTS, Cinetheodolites, MIGORS)
- Command Destruct
- Communication
- Weather
- Range Safety
- Timing

B.1.2.3 KSC

Because it is a separate entity, NASA's Kennedy Space Center is addressed later in its own section. The KSC area does contain the following ER assets:

- Telemetry site (TEL-4)
- Optics sites [Playalinda Beach DOAMS, Universal Camera Sites (UCS)]
- Radars (19.14, 19.17)
- Weather

The MOTR radar, presently at CCAS, is being considered for relocation to KSC.

B.1.2.4 JDMTA

Background

The first Eastern Range tracking station south of Patrick AFB is the Jonathan Dickinson Missile Tracking Annex (JDMTA). JDMTA is located 120 miles south of Patrick AFB near Jupiter, Florida on 11 acres of land that is a part of a Florida state park known as Jonathan Dickinson State Park. The facility was constructed over 1985-86 to support Navy trident missile testing³⁵¹ and to provide a south Florida tracking site that avoids looking through the attenuating rocket exhaust plume. When it became operational in 1987, it permitted the Grand Bahamas tracking station to be shut down permanently.

Instrumentation

³⁵¹ <http://www.computersciencesraytheon.com/home.html>

JDMTA is a state-of-the-art site (Figure B.1-15 & B.1-16) that includes the following systems:

- Telemetry (4 TAA-50s)
- Radar (28.14)
- Command Destruct (2 redundant systems)
- Translated GPS Ranging System (TGRS)
- SATCOM (2)
- Microwave relay to Cape
- Timing



Figure B.1-15 JDMTA (Aerial View)



Figure B.1-16 JDMTA (Ground View)

JDMTA provides in-flight monitoring of launch vehicle performance, electronics, and associated subsystems. During a launch, if and when it becomes necessary to protect life and property, the command destruct system is remotely activated from the Cape should a launch vehicle veer off course. The large TAA-8 telemetry antenna shown in Figures B.1-15 and B.1-16 was removed in the early 90’s and the SATCOM antennas added. Many of these systems will be discussed under the Instrumentation section.

B.1.2.5 Antigua

Background

Antigua Air Station is the next tracking station south of JDMTA. It is located on the island of Antigua, West Indies (Figure B.1-17). Antigua is one of the northeastern most islands in the Leeward Island chain and is approximately 1,250 nautical miles southeast of Patrick Air Force Base. The hilly island is approximately 16 miles across at its widest point east-west, 12 miles across north to south, and has a population of 65,000.³⁵²



Figure B.1-17 Antigua, West Indies

³⁵² <http://computersciencesraytheon.com/htmlFiles/Antigua%20AS.html>

Columbus discovered Antigua in 1493. Antigua, with adjacent islands Barbuda and Redonda as dependencies, became an associated state of the Commonwealth in 1967 and achieved full independence in 1981³⁵³. As a part of a World War II Lend-Lease deal, the UK granted the U.S. a 99-year lease on territories in Antigua, Bermuda, Argentina, and other islands in exchange for 50 WW-I destroyers³⁵⁴. Most of the Antigua land was returned to the British at the end of WW-II with the option to reuse the land at a later date. In the early 50's, a new arrangement was signed that granted the U.S. rights to build the present day Air Base and tracking station on part of the old Coolidge Base. This was renegotiated with Antigua after it obtained independence in 1981. The adjacent former Navy base was turned over to the Antiguan government in the early 90's.

Antigua Air Station population includes the station commander, a Civil Engineering quality assurance evaluator and approximately 150 contract personnel. Computer Sciences Raytheon (CSR), the prime contract authority, conducts spacecraft tracking operation, maintenance, supply, and support operations.

Instrumentation

Antigua includes the following systems:

- Telemetry (TAA-8, TAA-3) [Figure B.1-18]
- Radar (91.14)
- Command Destruct (2 redundant systems)
- SATCOM (2)
- Timing

The primary mission of Antigua Air Station is to provide telemetry and radar-tracking data supporting space launches out of the Eastern Range. The unit also has the secondary mission of providing radar-tracking data for locating and cataloging space objects in support of U.S. Space Command's Space Surveillance Network.³⁵⁵

A Consolidated Instrumentation Facility (CIF) was built in the 80's. Telemetry systems were quickly relocated to this facility in the mid-90's after a hurricane destroyed the adjacent old telemetry building. Command destruct equipment was relocated to the CIF in September 1998, enabling the closure of NASA's Bermuda site.

³⁵³ <http://www.bizzz.com/caribbean/resources/frame/about.htm>

³⁵⁴ <http://www.navy.mil/naval/deal.htm>

³⁵⁵ <https://www.patrick.af.mil/45LG/antigua.htm>



Figure B.1-18 Antigua Telemetry Antennas

B.1.2.6 Ascension

Background

The southernmost ER tracking station is at Ascension Island. Ascension Island is a British territory located in the South Atlantic more than 5,090 miles southeast of Patrick AFB and about 500 miles south of the equator--halfway between South America and Africa (Figure B.1-19). Small and volcanic, the island is roughly circular with an approximate diameter of six miles and area of 34 square miles (Figure B.1-20 and Figure B.1-21).



Figure B.1-19 Location of Ascension Island



Figure B.1-20 Ascension Island

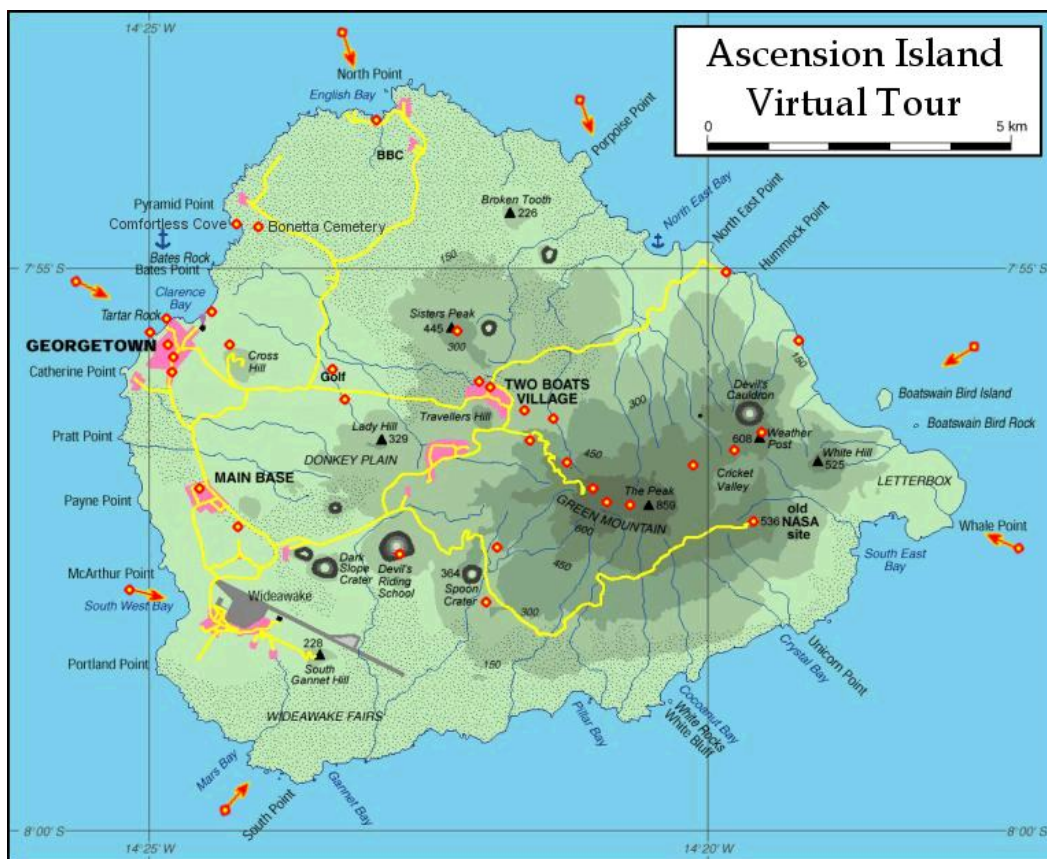


Figure B.1-21 Map of Ascension Island

Ascension was discovered by the Portuguese in 1501, and "found again" two years later on Ascension Day by Alphonse d'Albuquerque, who gave the island its name. Being dry and barren it was of little use to the East Indies fleets, so it remained uninhabited until Emperor Napoleon I was incarcerated on St Helena in 1815. A small British naval garrison was stationed on Ascension to deny it to the French³⁵⁶. The island later became the main relay point of the coaxial submarine cable system laid between the United Kingdom, Portugal and South Africa with links to South America and West Africa.

Less than 30 days after Pearl Harbor, the U.S. arrived on Ascension to construct (with British permission) an airfield (Figure B.1-22) to be used as a refueling station for planes being ferried to Europe, the Middle East and North Africa. More than 25,000 planes passed through Ascension during WW-II. Today, this airfield remains the intermediate stop for the twice-weekly Royal Air Force Tri-Star service between the United Kingdom and the Falklands. In addition, the USAF operates the weekly "Rangeliner" from Patrick AFB to Antigua and Ascension.



Figure B.1-22 Ascension Airfield (Wideawake Field)

In 1982, the island was re-garrisoned by British Forces to support operations in the Falkland Islands (also known as *Las Islas Malvinas*.)

In 1956, the Bahamas' agreement gave the U.S. permission to construct tracking stations at Antigua and Ascension. The Ascension station became operational in 1957 and today is the southernmost tracking station of the USAF Eastern Range. A NASA tracking station was built on Ascension in 1967, but has since closed down. British Cable and Wireless also operates an "Ariane" Earth Station on the Island on behalf of the European Space Agency.

Instrumentation

³⁵⁶ <http://www.ascension-island.gov.ac/ascension.htm>

Ascension instrumentation consists of the following:

- Radar (12.15 & 12.18)
- Telemetry (TAA-3C1, TAA-3C2)
- Communication (SATCOM)
- Timing
- Weather

A Consolidated Instrumentation Facility (CIF) was built in the 80's and equipment is slowly being relocated to this site.

B.1.2.7 Argentina

Background

Argentina is located in Newfoundland off the coast of Canada (Figure B.1-23). The same Anglo-American Lend-Lease Agreement of 1940 that gave the United States a base at Antigua, also provided the U.S. with territory in Newfoundland. Starting in 1941, a U.S. Navy Base was built in Argentina, Newfoundland (Figure B.1-24)³⁵⁷. Activity at the base remained at a high level until the early 1980's. The base was returned to Canadian control in 1995.



Figure B.1-23 Location of Argentina, Newfoundland

³⁵⁷ <http://agcwww.bio.ns.ca/mregion/ocean/argentina/TEXT/HISTORICAL/>



Figure B.1-24 Argentia Navy Base (1941)

In June 1993, a new range site was completed at Argentia, Newfoundland. This site was needed to support northbound flights of the TITAN IV from Cape Canaveral. The new site was built on the existing Navy base. The Navy base was later closed, but the site remains. Various plans are under consideration to relocate the site within the same general area.

Instrumentation

Argentia has the following instrumentation systems:

- Radar (53.17)
- Command Destruct
- Timing

Telemetry is provided by others using portable telemetry systems or by AFSCN telemetry equipment located at a site in New Hampshire.

B.1.3 Instrumentation

The Eastern Range has the following types of Range instrumentation:

- Radar
- Telemetry
- Optics
- Command Destruct
- Communication
- Weather
- Timing

B.1.3.1 Radar

To enable precision tracking and range safety throughout the 5000-mile range, the Eastern Range has an assortment of launch head and downrange radars. The following radars are used on the Eastern Range:

<u>Site</u>	<u>Designation</u>	<u>Type</u>	<u>Band</u>	<u>Dia-ft</u>	<u>Comments</u>
PAFB	0.14	MIPIR	C	29	Figure B.1-25
CCAS	1.16	AN/FPS-16	C	12	
CCAS	1.39	MOTR	C	12	Figure B.1-26
CCAS	1.8		X	NA	Sea surveillance
KSC	19.14	MIPIR	C	29	
KSC	19.17	MCBR	C	12	
JDMTA	28.14	MIPIR	C	29	
Antigua	91.14	MIPIR	C	29	Figure B.1-27
Ascension	12.15	TTR	C	40	
Ascension	12.18	AN/FPQ-18	C	29	Figure B.1-28
Argentia	53.17	MCBR	C	12	



Figure B.1-25 PAFB 0.14 Radar – MIPIR (rear)



Figure B.1-26 CCAS 1.39 – MOTR (Phased Array)



Figure B.1-27 Antigua 91.14 – MIPIR (front)
(Rear dish is TAA-8 Telemetry antenna)



Figure B.1-28 Ascension 12.15 - TTR

Modified AN/FPQ radars and telescopes provide precision tracking data from the outlying sites. These radars are supported with acquisition data from either AN/FPS radars and the Multiple Object Tracking Radar (MOTR) located at CCAS. The Precision Tracking radars are located at KSC (Merritt Island), PAFB, JDMTA, and on Antigua and Ascension Islands. All range radars are capable of either beacon or echo tracking, and providing real-time data to the ROCC. Surveillance radars at PAFB and CCAS provide aircraft and ship tracking in support of range control of restricted airspace and notification of pending launch to sea-going vessels³⁵⁸.

Ongoing modernization of the ER is intended to eliminate the need for most of these radars. As currently planned, the modernized ranges will use differential GPS tracking systems supplemented by seven radars at the ER. Three of the seven radars at the ER will be necessary only to support launches of the space shuttle, and three others will be located at downrange facilities to support ballistic missile tests and space object identification³⁵⁹.

A cross-reference for types of radars is as follows:

<u>Type</u>	<u>Radar Design</u>
MIPIR	AN/FPQ-14
TTR	AN/FPQ-15
MOTR	AN/MPS-39

In addition to these 10 radars, the Eastern Range often uses three NASA-operated C-band radars at Wallops Island. These are:

<u>Radar Design</u>	<u>Designation</u>
AN/FPQ-6	86.18
AN/FPS-16s	86.16I
AN/FPS-16s	86.16R

The Single Point Acquisition and Radar Control (SPARC) system located in the ROCC provides operational control and coordination of radars. The SPARC system enables the controllers to monitor and control all 2400 b/s acquisition data (high density data) on the Range, plus some off-range systems located at Wallops.

B.1.3.2 Telemetry

Telemetry Support consists of land based stations at Antigua, JDMTA, and Ascension Island. Real-time data are available at CCAS via satellite communication from Antigua

³⁵⁸<http://www.wslfweb.org/docs/roadmap/irm/internet/spacecon/init/text/antigu.rtf>

³⁵⁹http://www.nap.edu/html/streamlining_range/ch4.html

and Ascension Island, and via microwave from JDMTA. Telemetry aircraft support is provided by ARIA EC-135s and EC-18s from Edwards AFB.

A summary of Eastern Range Telemetry is as follows:

<u>Site</u>	<u>Telemetry</u>	<u>Dia-Ft</u>	<u>Comments</u>
KSC	TAA-3C	30	
KSC	TAA-24A	24	
JDMTA	TAA-50	50	4 systems
Antigua	TAA-8	80	Figures B.1-29, 30
Antigua	TAA-3C	33	Figures B.1-29, 30
Ascension	TAA-3C-1	33	Enclosed
Ascension	TAA-3C-2	33	Open
Ascension	Four Foot	4	Fixed antenna
Ascension	Shaped Beam	2.3 x 3	Fixed elliptic antenna

The two fixed Ascension antennas are pointed toward the offshore Sonobuoy Missile Impact Location system, which collects Trident impact data during the final 4-6 seconds of the trajectory.

The AFSCN New Hampshire site is sometimes used to cover northern trajectories.



Figure B.1-29 TAA-8 & TAA-3 at Antigua
(Prior to CIF being constructed)



Figure B.1-30 Antigua TAA-8 & TAA-3

B.1.3.3 Optics

The Eastern Range has an assortment of fixed and mobile metric optical systems near the launch head. There are four fixed sites at the following locations, listed from north to south:

Table B.1-2 ER Fixed Optical Sites

Site Designator	Instrument	Site Location	Lens Focal Length (Inches)	Comments
Playalinda Beach	DOAMS	KSC	100 to 400	Canaveral National Seashore
CB DOAM	DOAMS	Cocoa Beach	100 to 400	Behind Ron Jon's Surf Shop
PIGOR	IGOR	PAFB	90 to 500	On A1A
MB ROTI	ROTI	Melbourne Beach	100 to 500	On A1A

DOAMS - Distant Object Attitude Measurement System (Figure B.1-31) are twin telescope systems combined on a single mount used to track distant objects. An acquisition camera is also mounted with the two telescopes. Three units were obtained from White Sands in the 90's. Two of the units were used to modernize the Cocoa Beach and Playalinda sites. The third unit was used for parts.

PIGOR – Is the name given to the Patrick IGOR. This fixed site (Figure B.1-32) is located on A1A, directly across from the Tech Lab and adjacent to the 0.14 Radar.



Figure B.1-31 DOAMS



Figure B.1-32 PIGOR (front)

ROTI - The Recording Optical Tracking Instrumentation was constructed by mounting a telescope on a gun mount.

In addition to the four fixed sites, there are 24 Universal Camera Sites (UCS) that can take an assortment of mobile optical systems (Table B.1-3). The mobile units include both metric and non-metric trackers.

Table B.1-3 ER Mobile Optical Instruments

System	Metric	Lens Focal Length (inches)	Comments
ATOTS	Y	180 to 500	Advanced Transportable Optical Tracking System
Cinetheodolites	Y	60 to 120	
MIGOR	Y	90 to 500	Mobile Intercept Ground Optical Recorder
IFLOT	N		Intermediate Focal Length Optical Tracker
MOTS	N		Mobile Optical Tracking System
KTM	N		Kineto Tracking Mount

ATOTS – The Advanced Transportable Optical Tracking System (Figure B.1-33 and 34) was designed and built by the Range Contractor in the late 80's. These NASA-funded units were built to replace the MIGORs; however, portions of the MIGOR systems still remain. Each of the two ATOTS was built on a stock Fruehauf lowboy trailer. A firm in Las Cruces, NM constructed the forward room. The trailers were then delivered to Patrick AFB, where the rear room, astrodome, instrument, sub-frame, console, racks and accessories were installed. During tracking, the instrument is lowered on to jacks; this prevents movement inside the trailer from affecting the optics.

KTM – Kineto Tracking Mounts are trailer mounted optical trackers (Figure B.1-35).

Besides the optics listed in the above tables, most systems include acquisition cameras and lens to assist in acquiring targets.

The Eastern Range has a large assortment of standard motion picture and video cameras that can be mounted on the systems listed above. More than 200 motion picture cameras in 16-mm, 35-mm and 70-mm formats are available for general range use. Range assets also include more than 160 still cameras. These are often set up to be remotely operated near the launch site.

All metrics optics coverage is coordinated through and monitored by the Metric Optics Control (MOC) console located in room 158 in the ROCC.



Figure B.1-33 ATOTS



Figure B.1-34 ATOTS Telescope

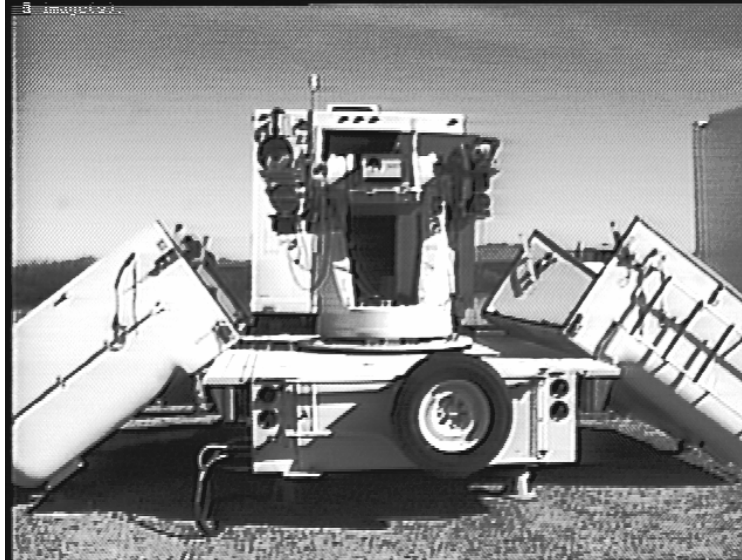


Figure B.1-35 KTM

B.1.3.4 Command Destruct

Command Destruct capabilities are provide at the following sites:

- Cape Canaveral Air Station (CCAS)
- JDMTA
- Antigua
- Argentina

Wallops Island also provides support for some ER missions. Each Command site has redundant but totally separate systems. The redundancy originates at the power source and continues through the transmitters and other components all the way up to the antennas. Each system also includes an ACME unit and is interconnected to the Flight Control Officer (FCO) at the Central Command Remoting System (CCRS).

ACME - This standalone, redundant, special test system that provides independent verification of the quality of transmitter secure-mode Command messages. It can receive, demodulate, archive and analyze transmitted messages. Out-of-tolerance conditions are flagged to the operator. The ACME unit can analyze functions in the Unmanned Secure, Manned Secure, ER Normal and Trident modes.

CCRS – The Central Command Remoting System is the nerve center of the Command Destruct System (CDS). It is physically located in the ROCC. The CCRS has bi-directional data links to command transmitter sites located at CCAS, JDMTA, Antigua, Wallops Island and Argentina. Wallops Island is not a part of the Eastern Range but is often used to support ER missions. All sites switch to the remote mode during a launch and transfer control to the FCO at the CCRS.

CCAS

The Cape Command facility at CCAS contains two completely independent command systems (Cape 1A and Cape 1B). Each system is located in its own building and has dual independent streams. The buildings are adjacent and interconnected. Both systems support all Digital Range Safety (DRS) and Inter-Range Instrumentation Group command modes. The Cape 1A system has Pilot Tone capability. The previously operating Cape Low Power system has been disconnected. Each Cape 1A and 1B system can operate in either a local or remote mode. The local mode is used during checkout only. Control is switched to remote and given to the Flight Control Officer (FCO) at the Central Command Remoting System (CCRS) at the ROCC. The ACME for Cape Command is physically located on the Cape 1A site, but is shared between both sites.

The Cape 1A Command System is the newer of the two systems. Redundancy begins with the power connection, which consists of two UPS protected independent power feeds. Each stream has a 10kW transmitter and can feed either a steerable antenna or an omni antenna.

The Cape 1B Command System is the older of the two systems. It has dual-redundant command streams starting with FPL industrial power feed to one side and an UPS diesel motor generator set on the other. Each stream has a 10 kW transmitter; normally operated in the 7 to 10 kW range. Output is via two steerable Canoga Quad helix antennas or a single Rozendal Omni-directional antenna.

JDMTA

The JDMTA Command system was the first stage of installing new state-of-the-art Command systems on the ER. It is a dual stream system with complete redundancy, starting with independent power sources. Stream 1 is powered by motor generators and backed up by an UPS. Stream 2 is also powered by motor generators but without the UPS. Each stream uses 10 kW transmitters that feed either DATRON steerable antennas inside radomes or exterior broad-beam antennas. The latter are used exclusively for Navy support.

Antigua

Antigua is the southernmost site with Command Destruct capabilities. Once the missile is out of sight of Antigua, it is no longer possible to destroy the missile. Antigua has Command System #1 and Command System #2. Each system is totally redundant but separate. The redundancy originates at the powerhouse and continues through the system; all the way to the two steerable antennas. Antigua utilizes two solid-state 4kW transmitters.

Argentina

The Argentina site is normally used only during special northern launches of the Titan IV. Argentina has two independent Command streams powered by a pair of diesel motor-generator sets. One set powers both streams while the other is used as backup power. There is no UPS or automatic switchover functionality. Each Command stream includes an ACME unit that can receive, demodulate, archive, and analyze the transmitted messages. Out-of-tolerance conditions are flagged to the operator. Argentina utilizes two solid-state 1.2kW transmitters and two steerable quad helix antennas. Command equipment is housed in a trailer. The antennas are under radomes to protect them from the elements.

B.1.3.5 Communications

The Eastern Range has an extensive communication network consisting of the following:

- Communication Satellites
- Microwave links
- High Frequency (HF) radio
- Landlines
- VHF/UHF

These are used to support and connect the sites and stations of the ER to each other and the world.

CCAS

CCAS is the focal point for all Range communication, Range user nets, and commercial carriers to other Government agencies and the world. Communication in and out of CCAS consists of the following:

- SATCOM
- Commercial Satellite / Landline
- DSCS Satellite / Landline
- Inmarsat
- Microwave Link
- Landlines
- HF
- UHF/VHF

SATCOM - The SATCOM (Satellite Communication) equipment at CCAS was installed under RSA-1. It is used to communicate with other SATCOM stations at JDMTA, Antigua and Ascension. This system has two completely independent strings that

terminate at dual 16.4-meter antennas located near the ROCC. Only one string is used at a time; because only one satellite transponder was leased. SATCOM is relayed via a leased INTELSAT geo-synchronous satellite located over the Atlantic. Capacity is 1.544 Mbps.

Commercial Satellite / Landline – This combination link is used to communicate with Antigua. A MCI/WorldCom earth station on Antigua routes the signals to a similar station in Houston. A leased landline routes the signal into CCAS. This 1.544 Mbps circuit can be configured to carry voice, data and video.

DSCS Satellite – The DSCS (Defense Satellite Communications System) military satellite provides one communication link to and from Ascension. The final route into the CCAS is via a landline from the DSCS earth station in Virginia.

Inmarsat – An International Maritime Satellite communication system is used to communicate between the ROCC and the LASS during Navy Trident launches. Dual Inmarsat-B antennas are located on the roof of the ROCC. Data rate is 56 kbps.

Microwave Link – The ER has a two-way Digital Speed-3 microwave link between JDMTA and the XY Building at CCAS. There is an extension from the XY Building to Tel-4. Communication interfaces are provided at Tel-4, XY building, Patrick AFB, Malabar, and JDMTA. Repeater-only stations are located at Stuart, Ft. Pierce, and Wabasso, FL.

Landlines – Fiber and copper landlines provide access from CCAS to Patrick AFB, KSC, around the Cape, and to the outside world.

HF- The High Frequency (HF) radio wave system consists of transmitters, receivers and antenna arrays located at Malabar, CCAS Communication Receiver building and Ascension. The ER has approximately 65 transmit frequencies allocated between 2 and 30 MHz. The transmit site for CCAS is located 40 miles south at Malabar, Florida. The receive site is on CCAS. HF is used for communication with Ascension, ships and aircraft. Links may handle data, teletype and voice.

UHF/VHF – Very High Frequency and Ultra High Frequency are used on the Range as follows:

- CCAS
 - VHF – Non-military aircraft control
 - UHF – Military aircraft, ships
- Ascension
 - VHF – Non-military aircraft control, ships, fire & security
 - UHF – Military aircraft, ships
- All
 - VHF/UHF – Land Mobile Radio (LMR) used by NOTU, RTSC, Army, 45 SW, JBOS

- UHF – Timing data

Unique Com systems and facilities at CCAS include the following:

- XY Building
- DCSS
- R/S TV Vans
- TVOC
- DMNE
- TMS
- VNE
- BIDDS
- CCTV
- DRCS
- Green Phone System
- ITL CCTV
- PAWS
- TOPS

XY Building – Almost all communication links at CCAS terminate in the XY Building. The facility contains the manual and automatic switching required to interconnect the Range and support missions.

DCSS - The Digital Communication Switching System is the switching network that controls the Range audio countdown nets, voice direct lines, monitor facilities, and recording functions for the ER.

R/S TV Vans – Range Safety uses the Range Safety TV Vans to view the flight characteristics of the vehicle from various angles during the first few seconds of launch. Each van is self contained for receiving images from a rooftop tracking camera, recording the images, and transmitting the images to TVOC via an 7-GHz microwave video link.

TVOC – The TV Operations Center is the hub for video operations on the ER. It has facilities to input, edit, record, archive, time-tag, process, and redistribute video from or to virtually anywhere on CCAS.

DMNE – The Digital Message Network is an automatic electronic message switching system that can receive, process, store, and route digital messages. It is located in the ROCC.

TMS – The Transport Management System is used for point-to-point multiplexing of ER circuits. It is located at the ROCC.

VNE – The Video Network Element is a video distribution service that allows video feeds to be dispersed among the various ROCC user positions.

BIDDS – The Base Integrated Data Distribution System provides 11,000-voice/data line capabilities to support communications at CCAS. The main system is located in the XY building with remote systems at the VIB, Southwest Terminal Building, E&L Building and the ROCC.

CCTV – The Closed Circuit Television is a video system that uses optics technology to capture real-time images and video recordings and transmission technology to process and distribute the images. The system includes the fixed-site cameras, mobile cameras, XY building video patch and the TVOC.

DRCS – The Digital Range Communication System provides voice communications for Range Operations. It provides users with switching capabilities and digital conference networks to support launch operations. This system is replacing TOPS.

Green Phone System – This 1950's-era analog phone system still provides point-to-point communication for all operation locations. Approximately 2000 green phones are still in service on the ER as of 2002. Because of their simplicity and reliability, no plans exist for their removal in the near future.

ITL CCTV – The Integrated, Transfer, and Launch complex Closed Circuit Television is used to control 74 real-time cameras supporting the Titan vehicle.

PAWS – The Public Aural Warning System is located in the XY Building and controls nine zones and over 200 outputs at CCAS.

TOPS – The Transistorized Operations Phone System provides operational voice communication throughout the Range. The ER has approximately 7500 TOPS units. The system is being replaced with the DRCS.

JDMTA

Communication in and out of JDMTA consists of the following:

- SATCOM
- Microwave links
- Landlines

SATCOM - JDMTA has a SATCOM link back to CCAS installed under RSA-1. This system has two completely independent strings terminating at dual 13-meter antennas located at JDMTA. One antenna was installed on top of the old TAA-8 pedestal; the other is located nearby. Only one string is used at a time since there is only one transponder under lease. SATCOM is relayed via a leased INTELSAT geo-synchronous

satellite located over the Atlantic. The receiving station at CCAS is located at the ROCC. Capacity is 1.544 Mbps.

Microwave Link – JDMTA has a microwave link back to CCAS.

Landlines – T1 and T2 landlines connect JDMTA to Tel-4.

Antigua

Antigua is the nodal point for all Caribbean area Com traffic. Communication in and out of Antigua consists of the following:

- Commercial Satellite / Landline
- SATCOM

The commercial satellite system is a MCI/WorldCom earth station on Antigua to a similar station in Houston with a leased landline back to CCAS. This 1.544 Mbps circuit can be configured to carry voice, data and video.

Antigua also has a SATCOM link back to CCAS installed under RSA-1. This system has two completely independent strings, which terminate at dual 13-meter antennas located at the Antigua CIF. Only one string is used at a time. SATCOM is relayed via a leased INTELSAT geo-synchronous satellite located over the Atlantic. The receiving station at CCAS is located at the ROCC. Capacity is 1.544 Mbps.

Ascension

Ascension is the net control station for ship and aircraft operations in Africa, Atlantic Ocean and the Indian Ocean. Communication in and out of Ascension consists of the following:

- DSCS Satellite
- SATCOM
- HF
- VHF/UHF

DSCS Satellite - The DSCS satellite is a part of a military global satellite network. One earth station is located on Ascension with a 38-meter dish. The other earth station is located in Virginia. A landline is used to get data back to CCAS. A DSCS III satellite is utilized. Data rates available to ER are 568 kbps.

SATCOM - Ascension also has a SATCOM link back to CCAS installed under RSA-1. This system has two completely independent strings terminating at dual 13-meter antennas located at the CIF. Only one string is used at a time since only one transponder was leased. SATCOM is relayed via a leased INTELSAT geo-synchronous satellite located over the Atlantic. The receiving station at CCAS is located at the ROCC. Capacity is 1.544 Mbps.

HF – Ascension is the U.S. HF communication node for the South Atlantic. It is used for communication with CCAS, ships and aircraft. This includes Navy P3 SMILS, ARIA, and LASS.

VHF/UHF – These frequencies are used to communicate with ships, planes, and for mobile communication on the island.

B.1.3.6 Weather

Eastern Range Weather systems are at the following locations:

- CCAS
- Ascension

The Antigua weather station has been closed for some years. Hurricane hunter planes were based in Antigua at one time. Patrick AFB has a Weather Radar, which supports CCAS.

CCAS

The CCAS Weather Station has a pair of Data General Meteorology System Computers (MSC) that receive, process, and store raw data from the ER upper air collection systems (Jimsphere and Meteorological Sounding System [MSS]). The MSCs then transmit processed meteorological profiles to Range Users and other Range systems.

Weather data is obtained and analyzed at CCAS using the following:

- MSS rawinsondes
- Jimsphere
- CGLSS
- WINDS
- ERDAS
- LPLWS
- MIDDS
- NLDN
- Weather Reconnaissance Aircraft

- Weather Surveillance Radar
- Doppler Weather Surveillance Radar
- Weather Rockets

MSS rawinsondes – The Meteorological Sounding System (MSS) uses a balloon-borne package in conjunction with complementary ground systems to generate atmospheric profiles for Range and Range User requirements. The MSS uses a 2.4-meter parabolic reflector inside radomes to track and communicate with the weather balloon and its data package.

Jimsphere – Jimsphere is a NASA-developed, constant volume balloon with 398 conical extensions that create drag and stabilize the balloon (Figure B.1-36³⁶⁰). The balloon and extensions are fabricated from Mylar. They are tracked using radar.



Figure B.1-36 Jimsphere Weather Balloon

CGLSS – The Cloud to Ground Lightning Surveillance System is a lightning detection system to record cloud-to-ground lightning strikes in the vicinity of KSC and CCAS. The system includes six Advanced Lightning Direction Finders (ALDF) (Figure B.1-37), each with its own GPS.

³⁶⁰ <http://www.sti.nasa.gov/tto/spinoff1996/48.html>



Figure B.1-37 ALDF

WINDS – The Weather Information Network Display System Surface is an array of instrumented meteorological towers (Figure B.1-38) at CCAS, KSC and surrounding areas. These provide near surface measurements of temperature, dew point, wind direction and wind speed. The towers cover the area in and around Kennedy Space Center and Cape Canaveral Air Station and are spaced an average of 2.5 to 4 miles apart.



Figure B.1-38 Weather Tower

ERDAS – The Eastern Range Dispersion Assessment System is an extension and enhancement of the Meteorological and Range Safety Support (MARSS) system.

LPLWS – The Launch Pad Lightning Warning System consists of 31 electric field mill sensors (Figure B.1-39) located throughout KSC and CCAS. These are connected to a computer and display. This data helps forecasters determine when electric charge aloft may be sufficient to create triggered lightning during launch, and to determine when to issue and cancel lightning advisories and warnings.



Figure B.1-39 Typical Field Mill

MIDDS – The Meteorological Interactive Data Display System is the primary data collection, management and display tool used by the 45th Weather Squadron (45 WS) to provide weather analysis, forecast and warning support to the ER.

NLDN – **The National Lightning Detection Network** is a commercial data service.

Weather Reconnaissance Aircraft – These aircraft are deployed during all expendable land-based launches to make in-situ observations of local weather. A Learjet 35 is presently used.

Weather Surveillance Radar – This commercial-off-the-shelf radar is located on the Headquarters building at Patrick AFB. Processing and display are located at the ROCC.

Doppler Weather Surveillance Radar – A Doppler weather radar is located adjacent to the Melbourne Airport; about 40 miles south of CCAS. This radar is owned and operated by the National Weather Service. The ER uses this as a backup to its weather radar. CCAS has a feed from the Melbourne site.

Sounding Rockets - Sounding rockets are sometimes launched from LC-43. In years past, induced lightning tests were performed at the Cape. These have been moved to an inland site in North Florida.

Ascension

The Ascension Weather station has a Meteorological Sounding System (MSS) that uses balloon-borne packages and complementary ground systems to generate atmospheric profiles for Range and Range User requirements. The MSS uses a 2.4-meter parabolic reflector to track the weather balloons and to send and receive data.

B.1.3.7 Timing

The ER Timing and Sequencing system has major equipment at the following locations:

- CCAS
- KSC
- JDMTA
- Antigua
- Ascension
- Argentinia

ER central timing is located in the ROCC at CCAS. It is the reference source for all timing signals transmitters on the ER. An extensive system of satellite, HF radio, L-Band radio, and landlines link the ER sites to one another. KSC is discussed under a separate section.

CCAS

The CCAS Station Clock provides all IRIG time signals, decade pulse repetition rates, and precision frequencies to all users in the ROCC. It is also used to synchronize all time signals and frequencies to all CCAS Site Clocks. The CCAS Station Clock is synchronized to the DOD Master Clock and monitored by the Range Master Clock. Historically, the CCAS Station Clock and the Range Master Clock have been regarded as the same system. The Station Clock is located in the ROCC.

JDMTA

The JDMTA Station Clock provides all IRIG time signals, decade pulse repetition rates, and precision frequencies to all users in the JDMTA Operations Building. It is also used to synchronize all time signals and frequencies to all JDMTA Site Clocks. The JDMTA Station Clock is synchronized to the DOD Master Clock and monitored by the Range Master Clock. The Station Clock is located in the JDMTA Operations Building.

Antigua

The Antigua Station Clock provides all IRIG time signals, decade pulse repetition rates, and precision frequencies to all users in the Antigua CIF. It is also used to synchronize all time signals and frequencies to all Antigua Site Clocks. The Antigua Station Clock is

synchronized to the DOD Master Clock and monitored by the Range Master Clock. The Station Clock is located in the CIF.

Ascension

The Ascension Station Clock provides all IRIG time signals, decade pulse repetition rates, and precision frequencies to all users in the Ascension CIF. It is also used to synchronize all time signals and frequencies to all Ascension Site Clocks. The Ascension Station Clock is synchronized to the DOD Master Clock and monitored by the Range Master Clock. The Station Clock is located in the CIF.

Argentina

The Argentina Station Clock provides all IRIG time signals, decade pulse repetition rates, and precision frequencies to all users at Argentina. The Argentina Station Clock is synchronized to the DOD Master Clock and monitored by the Range Master Clock.

B.2 KENNEDY SPACE CENTER

B.2.1 Background

B.2.1.1 General

NASA's John F. Kennedy Space Center (KSC) (Figure B.2-1) is the premier spaceport of the U.S. and, in many ways, of the world. It holds the following distinctions:

- Only U.S. manned Spaceport
- One of only 2 manned Spaceports in the world
- Only spaceport in the world to launch men to the moon

Although KSC is located directly adjacent to the Cape Canaveral Air Station on Merritt Island, KSC is a separate entity from the Cape Canaveral Air Station (Figure B.2-2) and the Eastern Range. KSC contains its own launch facilities and Launch Operations Control Center. NASA's KSC and the Air Force's Eastern Range share some facilities and property. The Eastern Range's Telemetry station (TEL-4) is physically located on KSC property along with some Universal Camera Sites (UCS) and one fixed camera site (Playalinda). NASA likewise uses some facilities on the Air Force side. NASA also utilizes the Eastern Range assets for its launches

KSC is located on the east coast of Florida approximately midway between Jacksonville and Miami, about 50 miles east of Orlando³⁶¹ (Figure B.2-3). KSC shares its property with the Merritt Island National Wildlife Refuge and the Canaveral National Seashore. KSC covers more than 140,000 acres; about one-fifth the size of Rhode Island. Only about 6,000 acres are currently used for Space Center operations, the remaining acres are a wildlife sanctuary³⁶².

KSC is one of 10 NASA Centers (Figure B.2-4). Most Centers support various development efforts associated with the Shuttle. All shuttle launches occur at KSC. Shuttle recovery occurs primarily at KSC, with Edwards AFB in California as a backup. A second backup site is located at White Sands, NM. The White Sands site has been used once for STS-3 in 1982.

Transoceanic Landing Sites (TAL) are available at Ben Guerir AB, Morocco; Moron AB, Spain; and Zaragoza AB, Spain. Additional information about Shuttle landing sites is provided in Appendix D.

³⁶¹ <http://www-pao.ksc.nasa.gov/kscpao/carpas/orlmap.htm>

³⁶² http://www.kennedyspacecenter.com/html/ksc_map.html

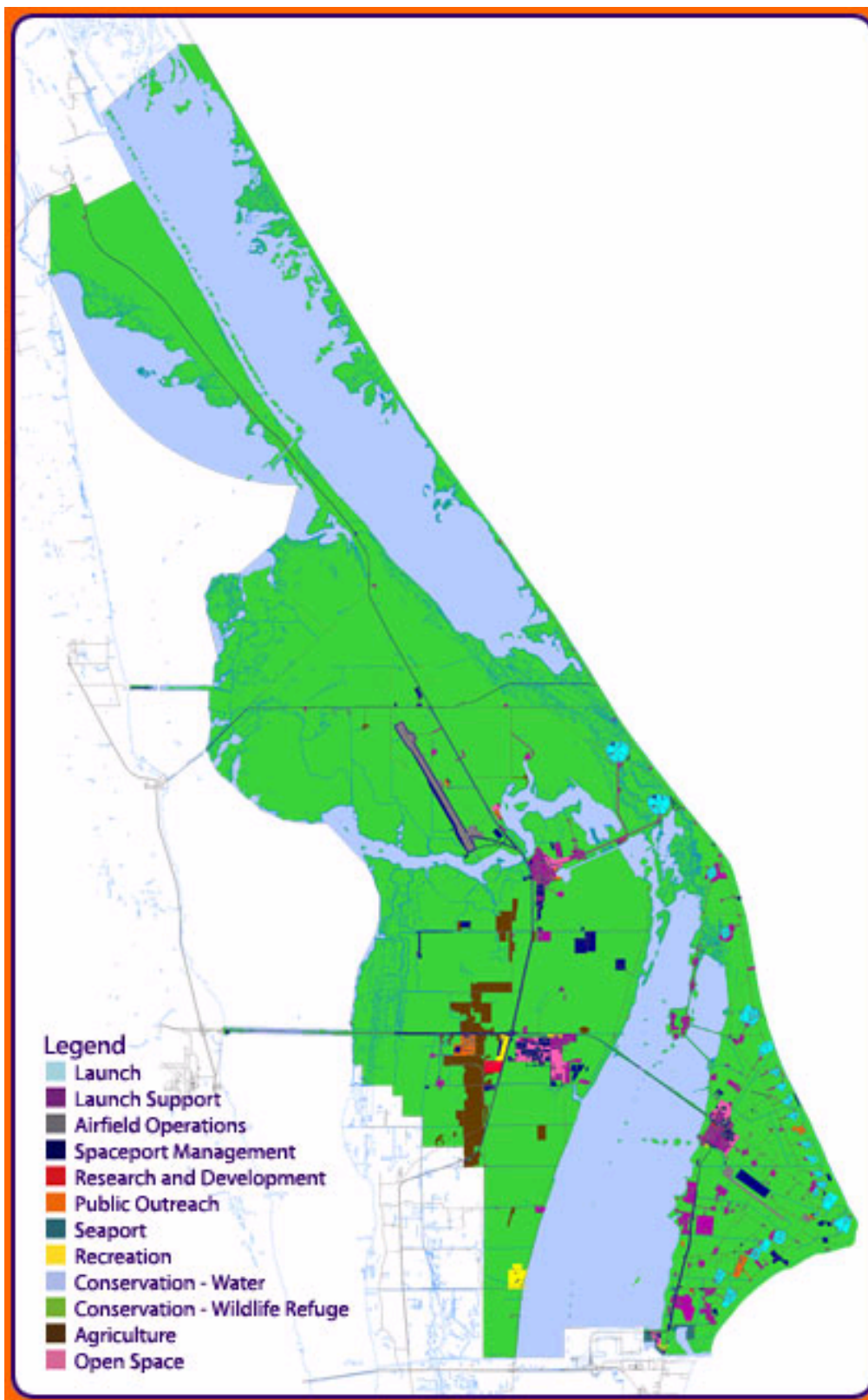


Figure B.2-1 KSC & Cape Canaveral Air Station (map)



Figure B.2-2 KSC & Cape Canaveral Air Station (photo)

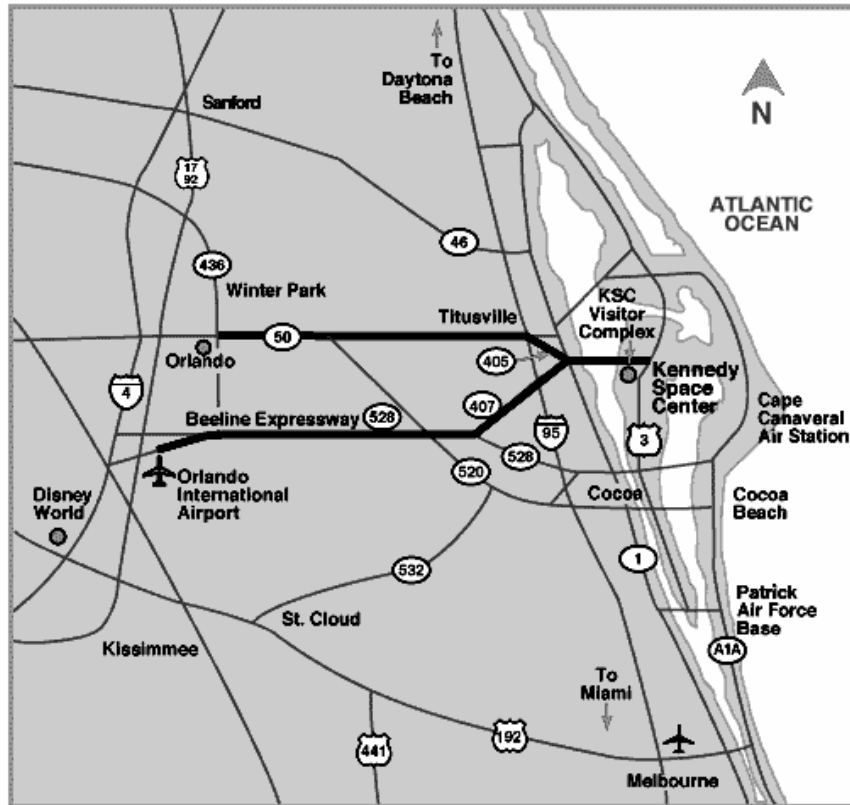


Figure B.2-3 Location of KSC



Figure B.2-4 NASA Centers

KSC's primary mission is processing and launching the Space Shuttle (Figure B.2-5).



Figure B.2-5 Space Shuttle Launch

B.2.1.2 History

NASA's history began on October 1, 1958, when NASA was formally organized out of the old National Advisory Committee for Aeronautics (NACA). KSC's history began three years later when the first land purchases on Merritt Island were made. The histories of KSC and NASA became closely tied during the race to land a man on the moon.

On Sept. 12, 1959, the Russian Luna 2 impacted on the Moon, a month later Luna 3 took the first pictures of the dark side of the Moon, and on April 12, 1961, Russian cosmonaut Yuri Gagarin became the first person to travel in space. The lunar space race had started.

On May 25, 1961, President John F. Kennedy announced that the United States would fly men to the Moon and back within the decade. His visionary challenge elicited congressional support for a program with rockets more powerful than any then available.

The lunar landing program was named Apollo, and the vehicle that would launch the Apollo spacecraft and its three-man crew to the Moon was the Saturn V. In addition, a new site had to be found to support and launch the lunar mission.

The race to the moon required simultaneous development in three critical areas:

- Manned Space Flight
- Space Vehicles
- Facilities and Procedures

Manned Space Flight

Six days after NASA was formed, the agency initiated Project Mercury, the first American human space flight program. On May 5, 1961, using a Mercury-Redstone, Alan Shepard became the first American to make a suborbital flight. Gus Grissom followed on July 21, 1961. On February 20, 1962, aboard a Mercury-Atlas, John Glenn made the first American orbital flight. In May 1963, the last Mercury mission was flown.

A little less than two years later, on March 23, 1965, the first manned Gemini-Titan II vehicle was launched. A year and half later, on November 11, 1965, the last of the ten Gemini vehicles was launched.

The Apollo program followed the Gemini program. The Apollo program got off to a bad start on January 27, 1967 with the Apollo 1 fire (B.2-6). The death of astronauts Grissom, White, and Chaffee caused a delay in the program while the Apollo module was redesigned. A summary of the Apollo program is given in Table B.2-1.



Figure B.2-6 Apollo 1 Fire

Table B.2-1 Summary of Apollo Program

Apollo	Launch Date	Vehicle	LC	Comments
1	1/27/67	Saturn IB	34	Apollo pad fire caused death of Gus Grissom, Edward White, and Roger Chaffee ³⁶³ (Figure B.2-6)
2				Mission name not used ³⁶⁴
3				Mission name not used
4	11/9/67	Saturn V	39A	Unmanned First Saturn V launch First KSC & LC-39 launch ³⁶⁵
5	1/22/68	Saturn IB	37	Unmanned First tests of Lunar Module ascent and descent stages
6	4/4/68	Saturn V	39	Unmanned Second Saturn V launch Experienced “pogo” effect Second stage lost 2 engines
7	10/11/68	Saturn IB	34	First manned Apollo flight
8	12/21/68	Saturn V	39A	Third Saturn V launch First manned Apollo/Saturn V flight First manned orbit of the moon Christmas eve broadcast from lunar orbit
9	3/3/69	Saturn V	39A	First flight of lunar module & test of the lunar module in earth orbit
10	5/8/69	Saturn V	39B	First lunar flight without landing; Lunar module closed to within 16 kilometers of the surface before re-docking with the orbiting command module. Only Pad B & Firing Room 3 use during Apollo ³⁶⁶
11	7/16/69	Saturn V	39A	First lunar landing on 7/20/1969 Neil Armstrong and Edwin Aldrin, Jr. walked on the moon while Michael Collins waited for them in the command module ³⁶⁷
12	11/14/69	Saturn V	39	Moon landing at Ocean of Storms and within 180 meters of Surveyor 3; vehicle struck by lightning twice on liftoff
13	4/11/70	Saturn V	39	First major in-flight emergency
14	1/31/71	Saturn V	39	Lunar landing; return to space for Alan Shepard
15	7/26/71	Saturn V	39	Extend lunar exploration ³⁶⁸ , First use of Lunar Rover ³⁶⁹
16	3/16/72	Saturn V	39	Extend lunar exploration
17	12/7/72	Saturn V	39	Extend lunar exploration First night Apollo launch Last Mission to the Moon ³⁷⁰

³⁶³ <http://www.hq.nasa.gov/office/pao/History/SP-4204/ch18-5.html>

³⁶⁴ <http://www.nasm.si.edu/apollo/AS01/a01sum.htm>

³⁶⁵ <http://www.hq.nasa.gov/office/pao/History/SP-4204/ch19-6.html>

³⁶⁶ <http://www.hq.nasa.gov/office/pao/History/SP-4204/ch21-6.html>

³⁶⁷ <http://www.hq.nasa.gov/office/pao/History/SP-4204/ch21-7.html>

³⁶⁸ <http://www.hq.nasa.gov/office/pao/History/SP-4204/ch23-1.html>

³⁶⁹ <http://www.hq.nasa.gov/office/pao/History/SP-4204/ch23-3.html>

³⁷⁰ <http://www.hq.nasa.gov/office/pao/History/SP-4204/ch23-7.html>

Skylab (Figure B.2-7), the first US space station, followed the Apollo lunar program. Skylab was launched into orbit on May 14, 1973 as a continuation of the Apollo program. This 91 metric ton structure was 36 meters (four stories) high, 6.7 meters in diameter and flew at an altitude of 435 km (270 miles). Three different Apollo crews manned *Skylab* during its 9-month mission³⁷¹.



Figure B.2-7 Skylab (1973)

On July 15, 1975, Skylab was followed by the Apollo-Soyuz (Figure B.2-8) mission. When splash down came on July 24, 1975, the Apollo hardware had completed its job and would never fly again³⁷².

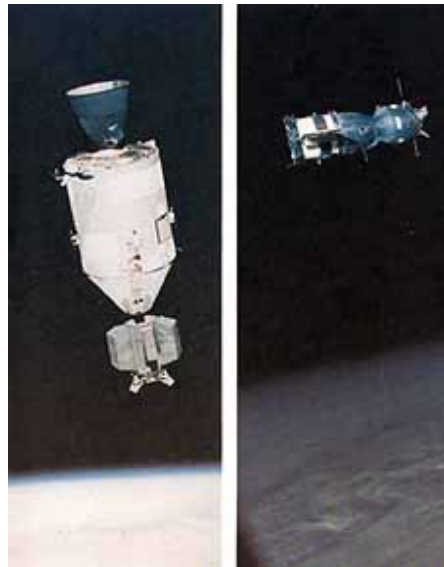


Figure B.2-8 Apollo / Soyuz (1975)

³⁷¹ <http://science.nasa.gov/ssl/pad/solar/skylab.htm>

³⁷² <http://www.hq.nasa.gov/office/pao/History/SP-4209/ch11-9.htm>

The next manned space flight, the Space Shuttle, is discussed in the following section.

Space Vehicles

Back in the late 1950s, the von Braun team had started the development of a super booster for the Army. The team had clustered eight rocket engines to see if a single stage could produce 1,000,000 pounds of thrust, far more than any rocket then known. In August 1959, the Defense Department decided it had no need for a rocket of this size and suggested that it might serve as a booster in NASA's space program. A month later, the program was transferred to NASA³⁷³. Later that year, the von Braun team of 5,000 civil servants, along with the Missile Firing Laboratory, was transferred from the Army to NASA.

The Saturn rocket program evolved from the Redstone and Jupiter rocket program in 1958 at White Sands. One of the first modern Saturn vehicles was the Saturn I. Eleven Saturn I launches were followed by several of the lighter and more powerful Saturn I B's. Early tests with the S-IB vehicle included the S-IVB as a second stage. The S-IVB was the third stage of the Saturn V lunar vehicle.

This three-stage Saturn V rocket generated about five times the thrust of the Saturn I. On November 9, 1967, the first Saturn V was launched from KSC's LC-39A. This 363-foot tall vehicle (Figure B.2-9) is still the largest vehicle ever flown. All launches prior to this Saturn V had occurred from the Cape Canaveral side of the Eastern Range; this was the first KSC launch.

During its latter missions, the assembled Saturn V lunar vehicle had the following major components:

- S-IC first stage (Figure B.2-10)
- S-II second stage (Figure B.2-11)
- S-IVB third stage (Figure B.2-12)
- Instrument Unit (ring above third stage)
- Lunar Lander (Figure B.2-13)
 - Ascent stage
 - Descent stage
 - Lunar Rover (Figure B.2-14)
- Service Module (Figure B.2-15)
- Command Module (Figure B.2-16)
- Apollo Capsule (Figure B.2-17)
- Launch escape system and adapter (Figure B.2-18)

³⁷³ <http://www-pao.ksc.nasa.gov/kscpao/kscstory/ch1/ch1.htm>



Figure B.2-9 Assembled Saturn V Vehicle



Figure B.2-10 **Saturn V – First Stage (S-IC)**



Figure B.2-11 **Saturn V – Second Stage**



Figure B.2-12 **Saturn V – Third Stage**



Figure B.2-13 Lunar Lander

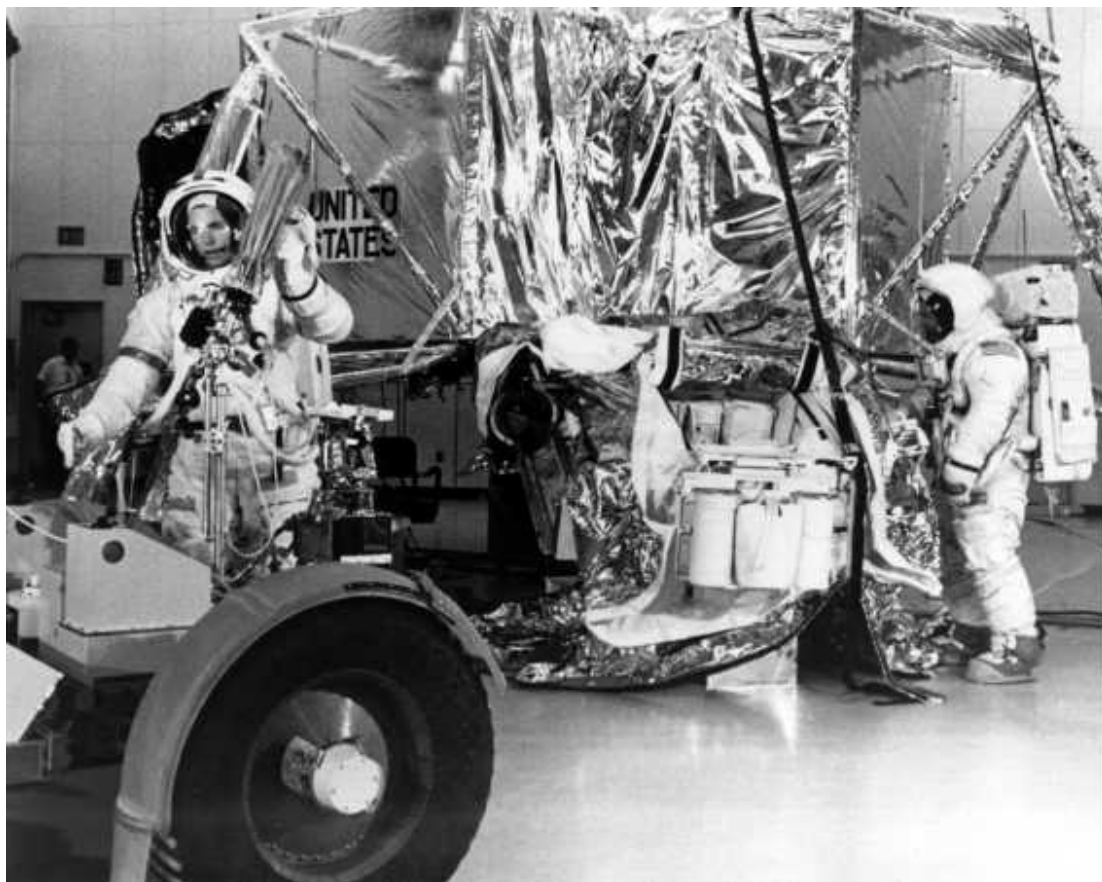


Figure B.2-14 Lunar Rover

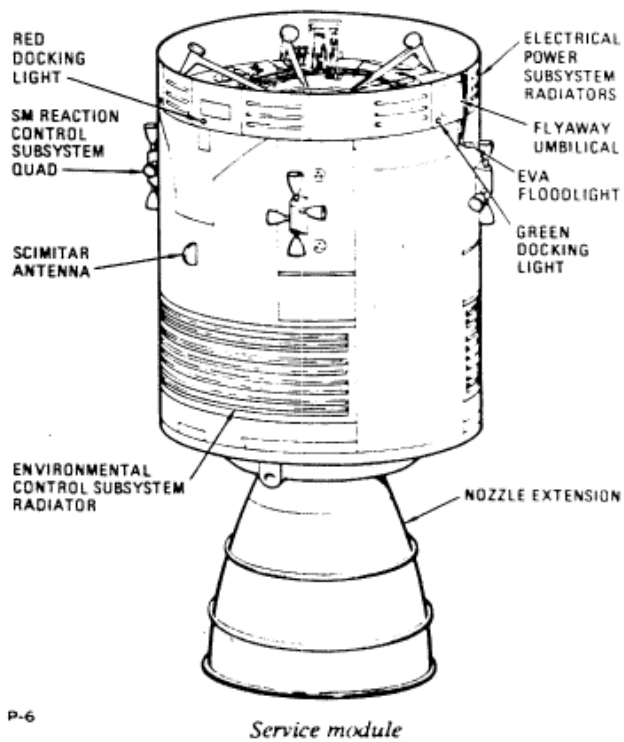


Figure B.2-15 Service Module

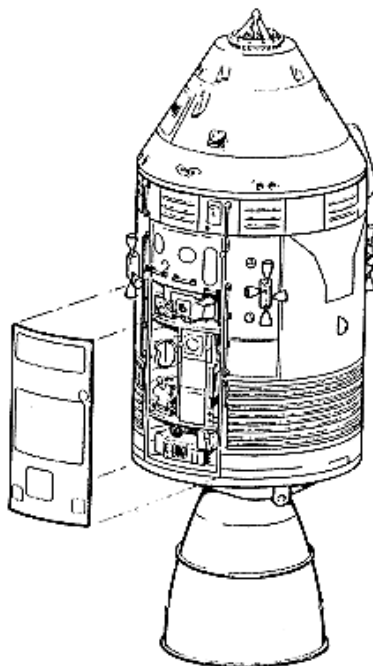


Figure B.2-16 Command Module

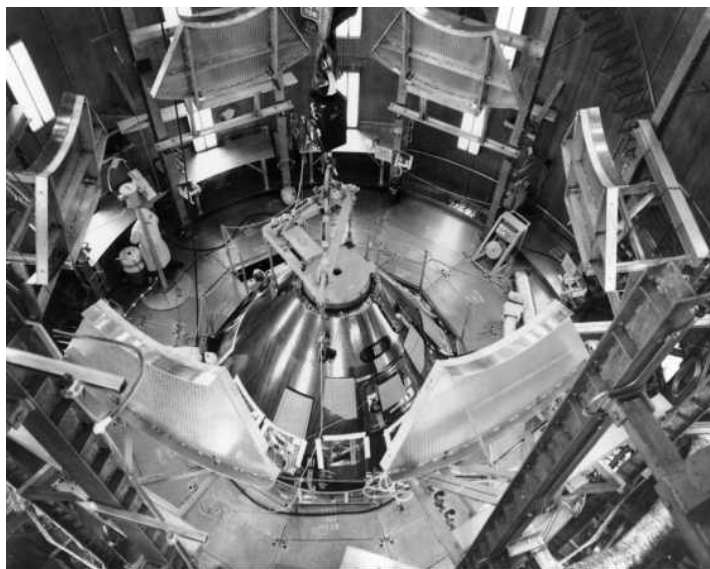


Figure B.2-17 **Apollo Capsule**

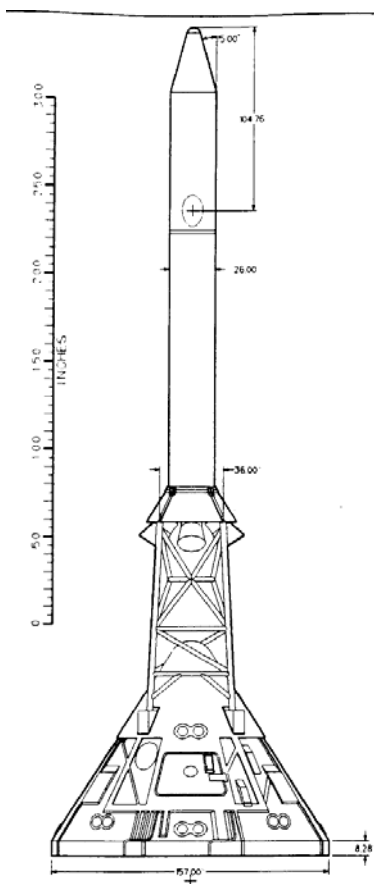


Figure B.2-18 **Apollo Capsule & Escape Rocket**

On July 16, 1969, Apollo 11 lifted off for the moon (Figure B.2-19). Four days later on July 20, 1969 the “Eagle” landed on the moon. At 10:56 PM, Neil Armstrong became the first person to set foot on the moon’s surface.

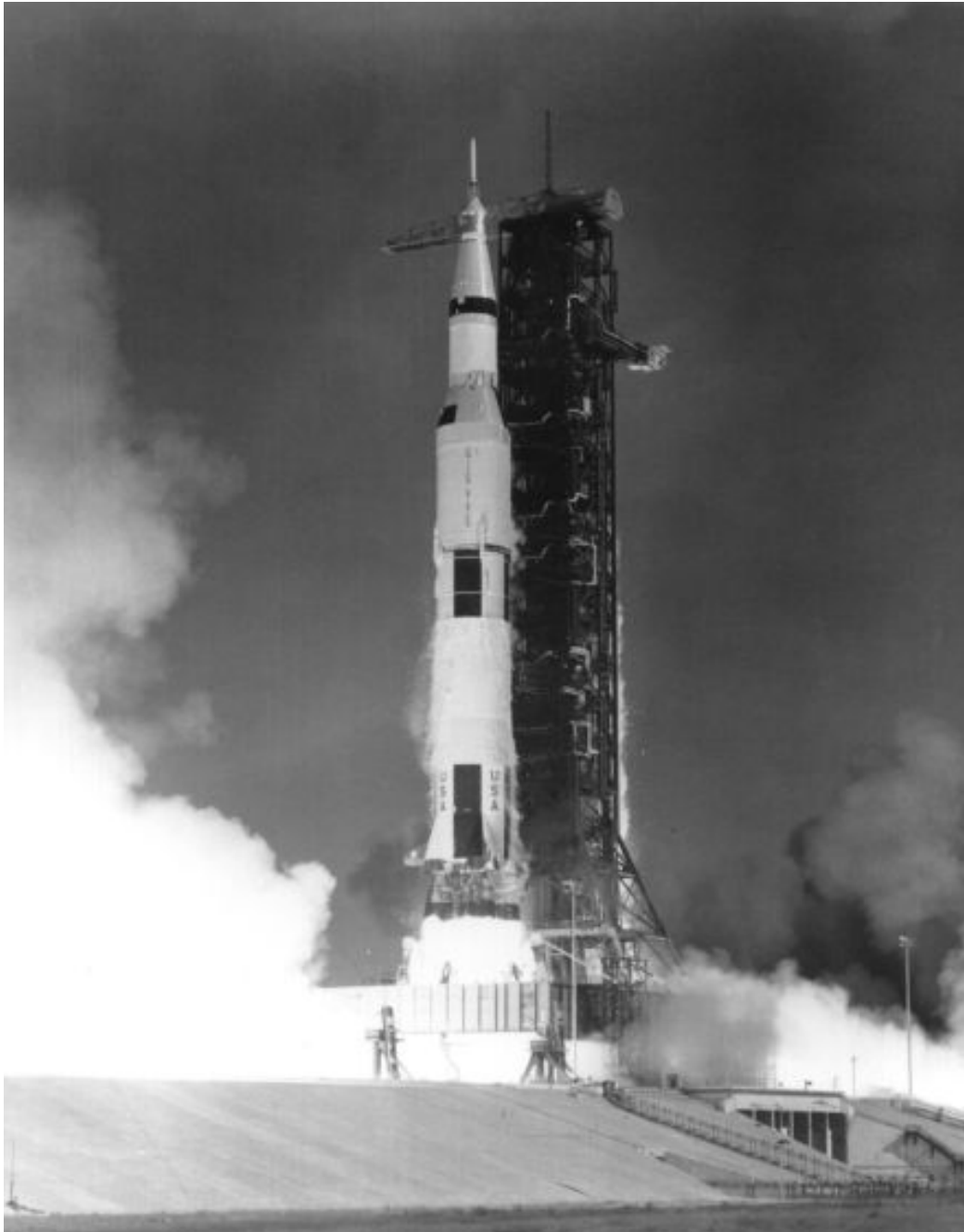


Figure B.2-19 Apollo 11 Lifts Off for the Moon on 7/16/69

As the Apollo-Saturn program came to an end, NASA began development of a reusable space vehicle called the Space Shuttle. Authority to build the Shuttle was given on August 9, 1972. The first shuttle to achieve flight was the Enterprise (Figure 3.2-20)³⁷⁴, when it separated from the Boeing 747 mother ship and glided back to Edwards AFB on August 12, 1977. On April 10, 1979, the Enterprise was ferried to KSC for trial fits. Later it was displayed in the U.S., Canada, and Europe. On September 20, 1985, the Enterprise was ferried to Dulles and turned over to the Smithsonian Institution. The first orbiter actually to fly into space was Columbia on April 12, 1981. STS-51L, the Challenger disaster (Figure B.2-21), occurred on January 28, 1986³⁷⁵. The newest orbiter is the Endeavour, which rolled out in 1991 and had its first flight (STS-49) on May 7, 1992³⁷⁶. The Space Shuttles and their rollout dates are summarized below³⁷⁷:

<u>Name</u>	<u>Designation</u>	<u>Delivered</u>
Enterprise	OV-101	1975
Columbia	OV-102	1979
Challenger	OV-99	1982
Discovery	OV-103	1983
Atlantis	OV-104	1985
Endeavour	OV-105	1991



Figure B.2-20 Enterprise on Test Flight (1977)

³⁷⁴ <http://science.ksc.nasa.gov/shuttle/resources/orbiters/enterprise.html>

³⁷⁵ <http://images.jsc.nasa.gov/iams/html/pao/STS51L.htm>

³⁷⁶ <http://science.ksc.nasa.gov/shuttle/resources/orbiters/endeavour.html>

³⁷⁷ http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/sts_overview.html#sts_program



Figure B.2-21 Challenger Accident (1986)

Facilities and Procedures

While the Saturn V was taking shape on the drawing boards, a suitable location had to be found to assemble, service, and launch the vehicles. Although the Cape Canaveral's 17,000 acres had proven adequate for previous space missions, larger facilities would be needed for the mammoth Moon rocket.

Dr. Debus, representing NASA, and Lt. Gen. Leighton I. Davis, representing the Department of Defense, organized a joint study to find a new launch site. They considered Hawaii, Padre Island off Texas, the California coast, Cumberland Island off the coast of Georgia, Mayaguana Islands in the Bahamas, Merritt Island (adjacent to the Cape), and others as possible sites³⁷⁸.

The study concluded that Merritt Island offered compelling advantages. Locating on Merritt Island also would allow NASA to share facilities of the Atlantic Missile Range, avoiding costly duplication. Dr. Debus and General Davis recommended the acquisition of the northern part of Merritt Island. The choice was endorsed by NASA and the Defense Department. Congress authorized NASA to acquire the property.

³⁷⁸ <http://www.hq.nasa.gov/office/pao/History/SP-350/ch-6-1.html>

KSC officially began in 1962 when land acquisition started. NASA took title to 83,894 acres by outright purchase. It negotiated with the state of Florida for use of an additional 55,805 acres of state-owned submerged land, most of which lies within the Mosquito Lagoon. The investment in property reached approximately \$71,872,000.

In July 1962, the Launch Operations Directorate at the Cape was separated from the Marshall Space Flight Center by executive order. It became the Launch Operations Center, an independent NASA installation, with Debus as its first director. It was renamed the John F. Kennedy Space Center in December 1963, in honor of America's slain president. In December 1964, launch elements of Houston's Manned Spacecraft Center (now the Johnson Space Center) were transferred to the Kennedy Space Center. The following October, Goddard Space Flight Center's Field Projects Branch on the Cape was incorporated into the Kennedy Space Center.

The challenge to put a man on the moon within the decade had been issued by the late President Kennedy and accepted by the American government and scientific and technical community. Next came the task of meeting that challenge through the design, construction and operation of a complete spaceport.

Construction at KSC began immediately after land acquisition. Design of the VAB actually started in 1961. The design changed as the vehicle design evolved. By 1965, the VAB was well into the construction phase (Figure B.2-22)³⁷⁹. Construction of the launch pads also began in 1961 and was completed in 1966 (Figure B.2-23).

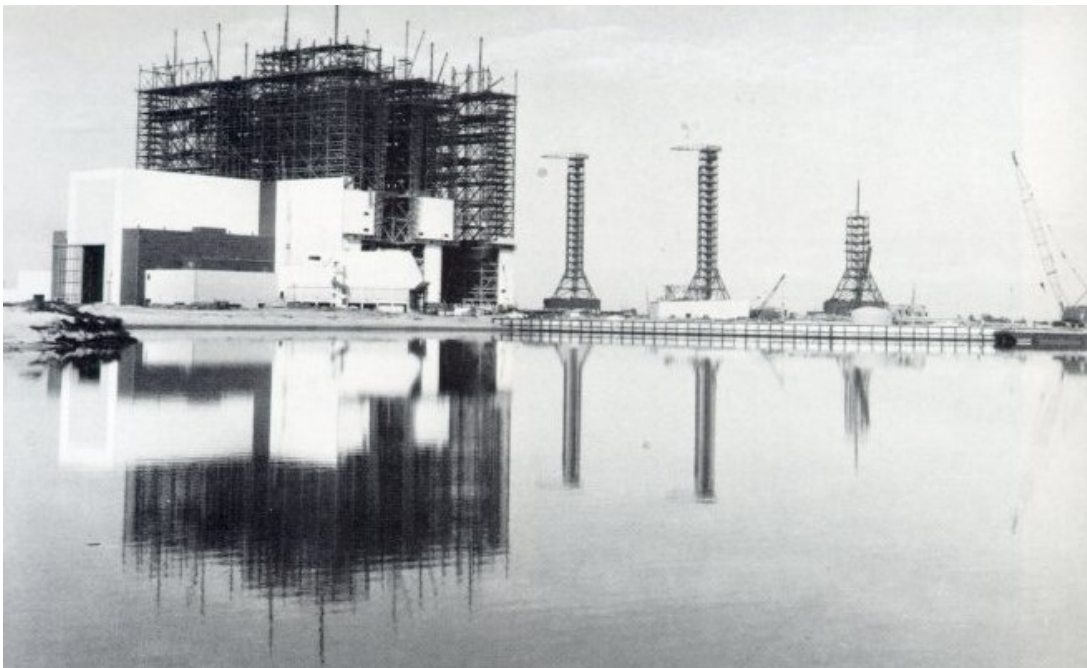


Figure B.2-22 VAB Under Construction (1965)

³⁷⁹ <http://www.hq.nasa.gov/office/pao/History/SP-350/ch-6-1.html>



Figure B.2-23 LC-39A in Mid 60's

A key factor to building the VAB and LCC was the method to transport the vertically assembled Apollo/Saturn V the three miles to the launch sites. Both rail and barge mounted methods were considered before selecting the crawler concept in June 1962. Marion Power Shovel Co. of Ohio was the low bidder. After running into various problems, they successfully had a crawler operational in January 1965. The crawler concept includes a crawler-transport, mobile launcher, mobile service structure, and service arms (Figure B.2-24)³⁸⁰.

³⁸⁰ <http://www.hq.nasa.gov/office/pao/History/SP-4204/ch13-1.html>

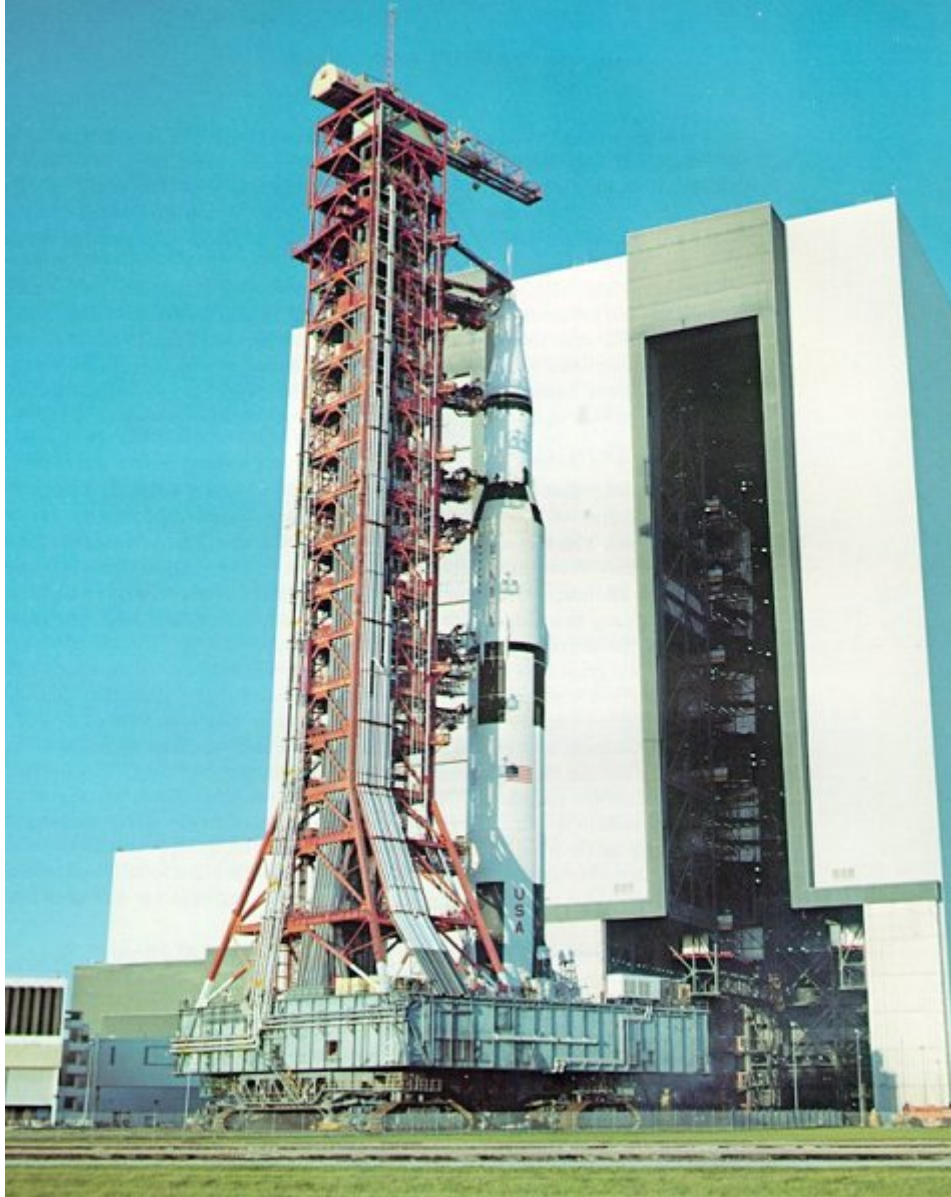


Figure B.2-24 Saturn V & Mobile Launch Platform on Crawler-Transporter

In order to track and communicate with the Apollo vehicles, NASA built a network of remote facilities around the world. By the launch of Apollo 9, the new system was operational at stations in Texas, Mexico, Ascension Island, the Canary Islands, Bermuda, Spain, Hawaii, Australia, Wales, and California. In addition, range instrumentation ships were used to fill in those areas not covered by land bases. The Range Ships³⁸¹ were discussed and listed under the Eastern Range section of this document. The early Range Instrumentation Ships started operation around 1960. The Bermuda station was also opened in 1960 and the Ascension site was activated in 1967.

³⁸¹ <http://www.usmm.org/msts/specialships.html>

On April 5, 1983, NASA launched the first Tracking and Data Relay Satellites (TDRS) (Figure B.2-25)³⁸². These satellites are still used to communicate with the Space Shuttle while it is on orbit. This space-based communication system enabled NASA to start closing remote sites. Ascension was closed in the late 1980's and Bermuda was closed in 1995. The full TDRS constellation with seven on-orbit satellites enables coverage of a significant portion of the earth (Figure B.2-26). TDRS data is received back on earth through two operationally identical ground stations near Las Cruces, NM (Figures B.2-27 & -28). The TDRS system (Figure B.2-29) supports the Space Shuttle, Hubble Telescope, and over 15 other programs³⁸³.



Figure B.2-25 Artist Concept of TDRS

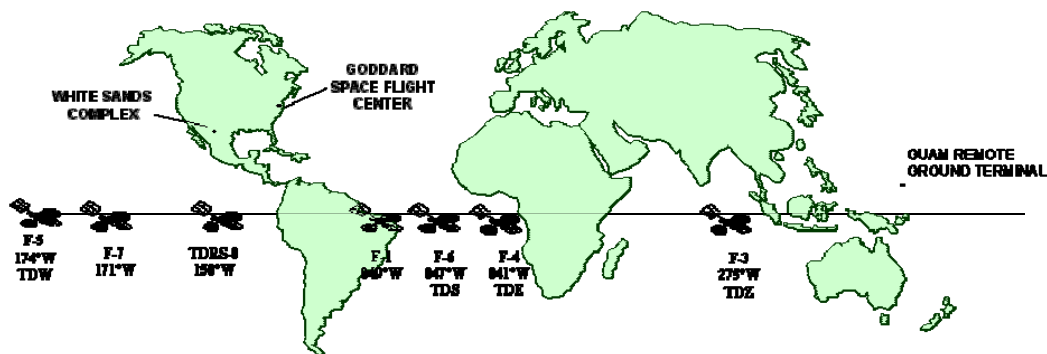


Figure B.2-26 TDRS Constellation

³⁸² <http://nmsp.gsfc.nasa.gov/tdrss/scraft.html>

³⁸³ <http://nmsp.gsfc.nasa.gov/tdrss/oview.html>



Figure B.2-27 TDRS White Sands Ground Terminal (WSGT)



Figure B.2-28 Secondary TDRS Ground Terminal (STGT)

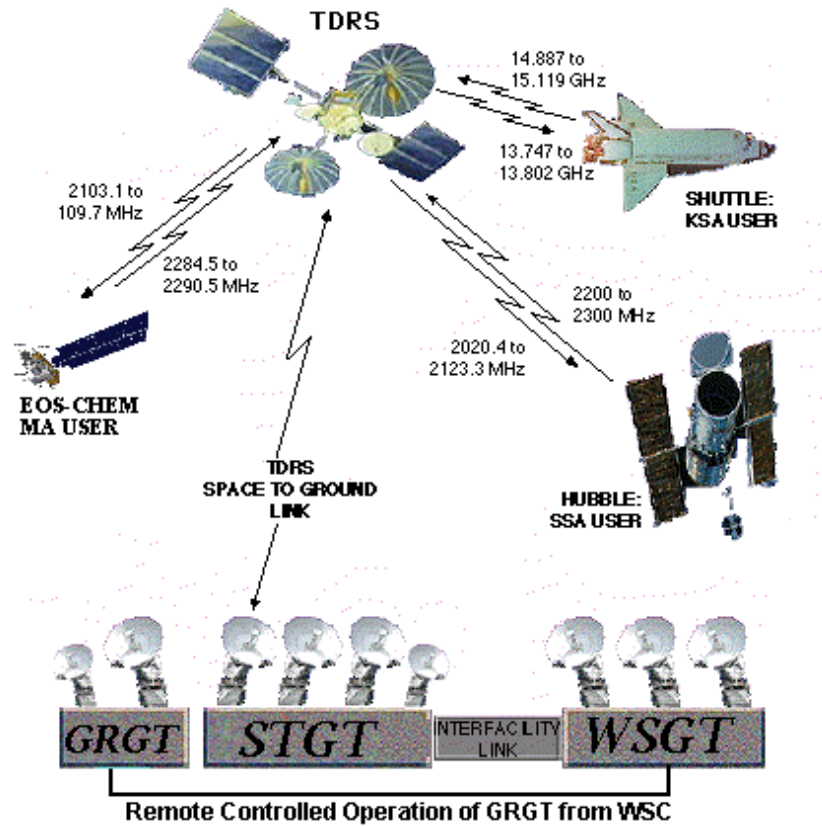


Figure B.2-29 TDRS Operation Concept

B.2.2 Facilities

As a major NASA center, KSC contains facilities for:

- Laboratories
- Testing
- Offices
- Warehouses
- Medical
- Security
- Crew training
- Meals
- Other organizations

To complete its primary missions of recovery, preparation and launching the Shuttle, KSC has the following special facilities:

- AE Hangar
- AF Hangar

- CD&SC
- CIF – Central Instrumentation Facilities
- Crawler-Transporter
- Cryogenics Laboratory
- HPF - Hypergolic Processing Facilities
- HQ – Headquarters Building
- LCC – Launch Control Center
- MILA – Merritt Island Launch Annex
- MLP – Mobile Launch Platform
- OPF – Orbiter Processing Facilities
- Recovery Ships
- SLF – Shuttle Landing Facility
- SSPF – Space Station Processing Facility
- VAB – Vehicle Assembly Building
- Visitors Center
- Launch Facilities – (LC-39A & 39B)

AE Hangar – Hangar AE (Figure B.2-30) is a NASA facility physically located on the Cape Canaveral Air Station. It is a multipurpose facility whose primary function is monitoring telemetry data from expendable rockets. It receives a telemetry feed from Tel-4 and audio/visual feeds from X-Y and TVOC. These are directed to consoles and screens in various control rooms. Hangar AE usually accommodates payload and vehicle personnel who monitor their respective flights. It also handles overflow from the ROCC.



Figure B.2-30 NASA's Hangar AE on Cape Canaveral Air Station

Hangar AE is also used for pre-launch preparations and check out of unmanned payloads. The building contains a high bay clean room (Figure B.2-31)³⁸⁴ complex in addition to the telemetry ground station, the Mission Director's Center (MDC), and offices for payload management and contractor personnel. The KSC NASA Payload Management and Operations Directorate use this building as its "communications center"³⁸⁵.



Figure B.2-31 **Clean Room at Hangar AE**

AF Hangar – Hangar AF, the Solid Rocket Booster Disassembly Facility, is another NASA facility on the Cape side of the Banana River. It was first used during Project Mercury. Today it is used to refurbish Solid Booster Rockets after they are retrieved and returned to land. The two recovery ships use the adjacent dock as their base of operation. Once at Hangar AF, the SRBs are unloaded onto a hoisting slip and mobile gantry cranes lift them (Figure B.2-32) onto tracked dollies where they are ‘safed’ and undergo their first washing³⁸⁶.

³⁸⁴ <http://acs.pha.jhu.edu/instrument/calibration/facilities/ksc/>

³⁸⁵ http://216.239.33.100/search?q=cache:uGgy5TG_nhkC:www.ksc.nasa.gov/elv/eastern.htm+&hl=en&ie=UTF-8

³⁸⁶ <http://www.floridatoday.com/space/weekly/w122897.htm>



Figure B.2-32 Recovered SRB Being Placed on Dollies at Hangar AF

CD&SC – The Communication Distribution and Switching Center is the communication hub for most of KSC. Most fiber and copper landlines are switched at this location. It also contains a satellite earth station for receiving NASA TV and other communications.

CIF – The Central Instrumentation Facility is the hub of instrumentation and data processing operations. It is three stories tall and contains 12,669 square meters (136,378 sq ft) of floor space and is located to the west of the Headquarters Building. The building houses offices, laboratories and test stations. Systems receive, monitor, process, display and record information received from space vehicles during test, launch, flight and landing. It also houses KSC calibration labs and the KSC administration computers³⁸⁷.

Crawler-Transporter - The Crawler-Transporters previously used to move the assembled Apollo/Saturn from the VAB to the launch pad are now used for transporting Shuttle vehicles (Figure B.2-33). KSC has 2 crawler-transporters. Each vehicle consists of four double-tracked crawlers, each 3 meters (10 ft) high and 12 meters (41 ft) long. Each of the 8 tracks on a vehicle contains 57 shoes per track and each tread shoe weighs about .9 metric tons (one ton). The Crawler/Transporter uses 16 traction motors powered by four 1,000 kW generators, driven by two 2,750 hp diesel engines. Two 750 kW generators, driven by two 1,065 hp diesel engines are used for jacking, steering, lighting, and ventilating. The KSC crawlers are the largest tracked vehicles in the world³⁸⁸.

³⁸⁷ <http://www-pao.ksc.nasa.gov/kscpao/facilities/cif.htm>

³⁸⁸ <http://www-pao.ksc.nasa.gov/facilities/crawler.htm>

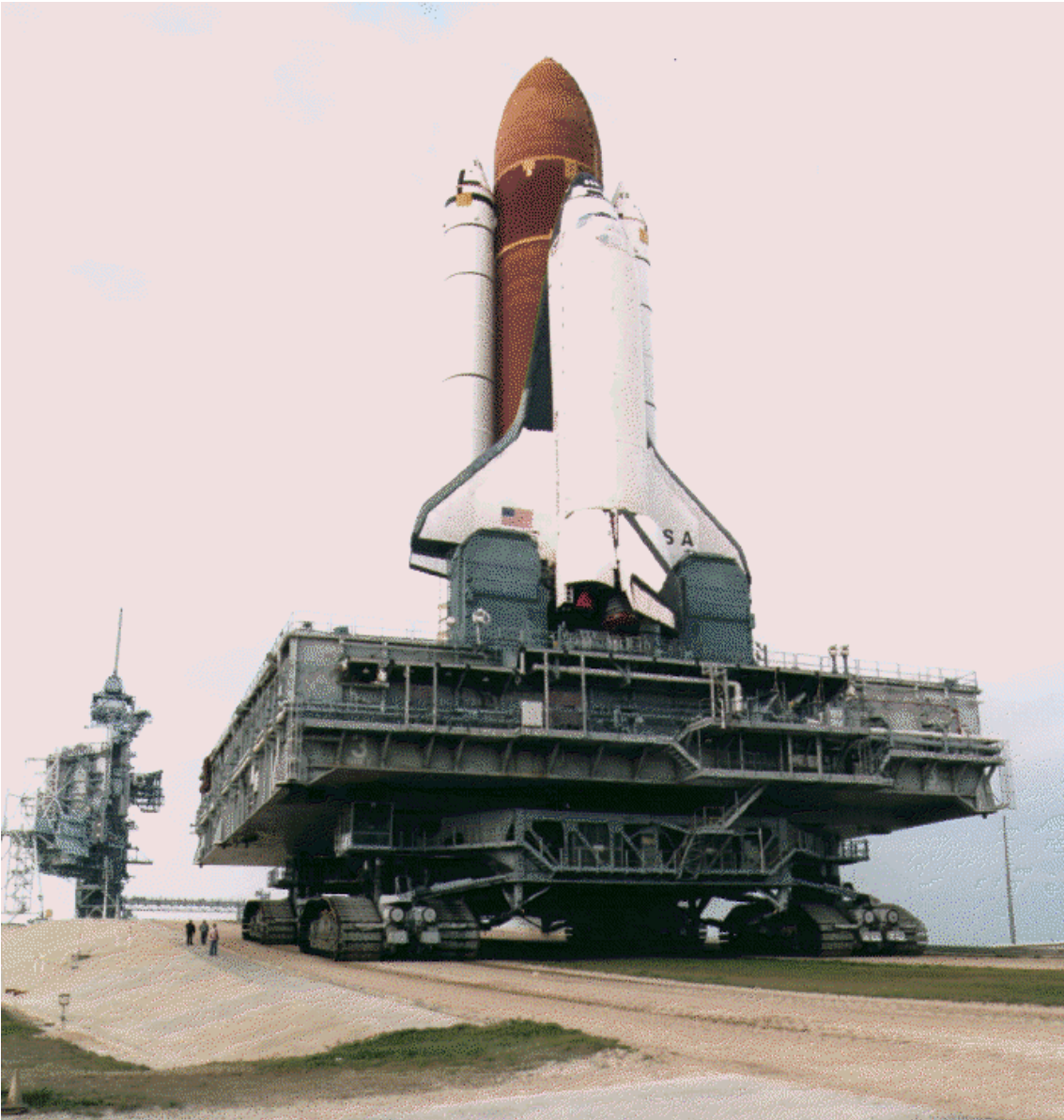


Figure B.2-33 Crawler-Transporter with MLP & Shuttle Approaching LC-39

Cryogenics Test Facility³⁸⁹ - KSC's Cryogenics Test Facility (Figure B.2-34)³⁹⁰ is a relatively new facility that opened in April of 2000. The goal of the facility is to establish the Cryogenics Testbed at Kennedy Space Center as a main resource for cryogenics and cryogenic engineering. NASA and Dynacs Engineering Co. jointly manage the facility.

³⁸⁹<http://spacelink.nasa.gov/NASA.News/NASA.News.Releases/Previous.News.Releases/00.News.Releases/00-04.News.Releases/00-04-11.New.Cryogenics.Testbed.Facility>

³⁹⁰ http://www.cryogenicstestbed.com/dynacs_inc_.htm



Figure B.2-34 KSC Cryogenics Test Facility

KSC's Cryogenics Testbed facilities include the Cryogenics Test Laboratory, Liquid Nitrogen Flow Test Area, Hazardous Test Area and the Launch Equipment Test Facility. Four technology focus areas, or core lines of work, are linked to key targets of the long-range strategic initiatives of NASA. These focus areas are: thermal insulation systems, cryogenic components, propellant process systems, and low temperature applications³⁹¹.

HPF – The Hypergolic Maintenance and Checkout Facility consists of three buildings in an isolated section of the KSC industrial area, approximately eight miles southeast of the Vehicle Assembly Building. This area provides all facilities required to process and store the hypergolic-fueled modules that make up the orbiter's reaction control system, orbital maneuvering system (Figure B.2-35)³⁹² and auxiliary power units³⁹³.

³⁹¹ <http://www.spacer.com/news/cryogenics-00a.html>

³⁹² <http://images.jsc.nasa.gov/images/pao/STS27/10063051.htm>

³⁹³ <http://science.ksc.nasa.gov/facilities/hmf.html>

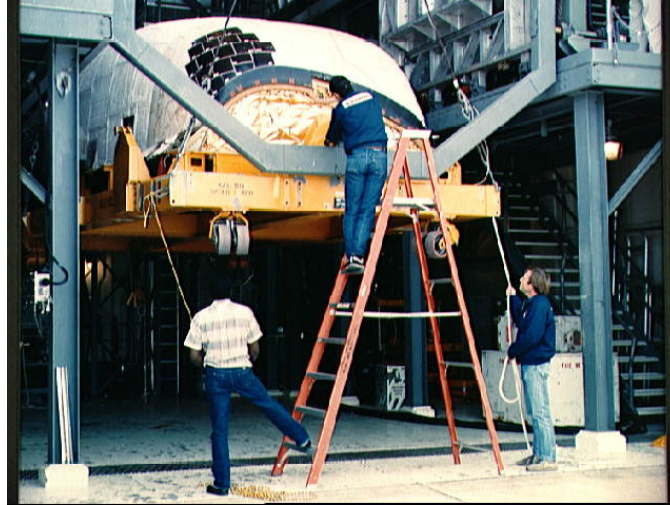


Figure B.2-35 Right Orbital Maneuvering System Being Placed in HPF Cell

HQ - The Kennedy Space Center Headquarters building (Figure B.2-36) is the administrative center for all spaceport activities. This facility houses the offices of the Center Director, management staff, personnel, procurement and several hundred contractor and support personnel. The Headquarters building also houses the KSC Library, Travel office, Film and Photo archive, photo processing shops, print shop and KSC security offices. The building is 439,446 square ft (40,824 square meters), is three stories high (except for a 4th story center section) and is made of reinforced concrete³⁹⁴.



Figure B.2-36 KSC Headquarters Building

LCC – The Launch Control Center (Figure B.2-37) is the brain of Shuttle launch activities. The LCC is a four-story structure located on the southeast side of the VAB and connected to it by an enclosed bridge for utilities. Office space and a utilities systems control room are located on the first floor. The control data subsystem occupies the core of the second floor. Four firing rooms (Figure B.2-38) occupy most of the third floor. The fourth floor is used for office areas. All four firing rooms can support software

³⁹⁴ <http://www-pao.ksc.nasa.gov/kscpao/facilities/hq.htm>

development or hardware checkout. Three firing rooms have the capability of supplying pre-launch checkouts at the OPF, VAB, and launch pads.



Figure B.2-37 Launch Control Complex (LCC)

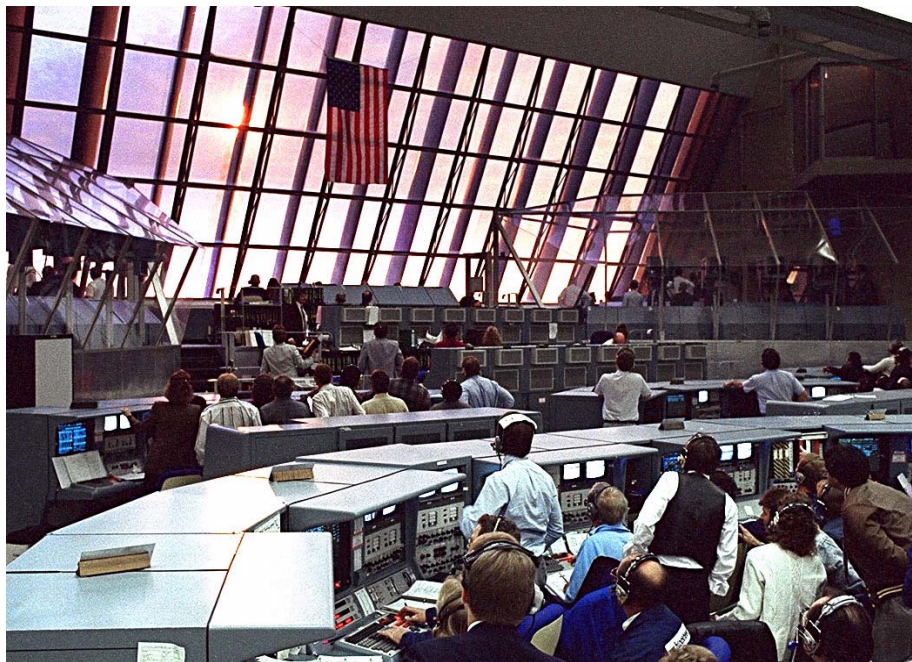


Figure B.2-38 LCC Firing Room During a Shuttle Launch

MILA – The Merritt Island Launch Annex (Figure B.2-39) is a NASA Goddard Space Flight Center (GSFC) Tracking Station located on Kennedy Space Center³⁹⁵. The station was established in 1966 by NASA's GSFC as one of the 17-member ground stations to support the Apollo program.



Figure B.2-39 Merritt Island Launch Annex (MILA)

In order to provide S-band communications around the Space Shuttle solid rocket booster plume (which contains aluminum perchlorate, and strongly attenuates high frequency S-band signals), a "wing site" tracking station was constructed some 40 miles north of MILA at New Smyrna Beach's Ponce De Leon Inlet (PDL). The PDL wing site communicates with the MILA base station via a fiber optic link.

In 1980, the MILA Relay System (MRS) was constructed to enable KSC area users to communicate via the Tracking and Data Relay Satellite (TDRS) in stationary orbit above the Atlantic Ocean. The MRS relays S-band and Ku-band signals for pre-launch verification of the user's compatibility with the space-based TDRS network. This "Bent Pipe" radio frequency MRS is unique in design, and is the only one in existence. (The first TDRS was launched April 4, 1983 on STS-6.)

In 1992, an Ultra High Frequency (UHF) voice system with cross dipole antenna was added to PDL to be used as a backup to the S-Band Forward Link during the time MILA is blocked by the Solid Rocket Motor plume.

³⁹⁵ <http://science.ksc.nasa.gov/facilities/mila/milstor.html>

In 1996, an Ultra High Frequency (UHF) voice system with a Quad-Helix Antenna was added to MILA to backup the UHF Teltrac Antenna in case of a Return To Landing Site Abort. This system displaced the Two In Flow S-Band Antenna.

MLP – The Mobile Launcher Platform (MLP) is the large block-like platform that supports the Shuttle. The steel MLPs are 25 ft. high, 160 ft. long and 135 ft. wide. They weigh 8,230,000 pounds. At the launch pad, with a fueled Shuttle on their 6-inch-thick decks, they weigh 12,700,000 lb. The MLPs are stored outside and adjacent to the VAB. To prepare for a launch, an MLP is picked up and carried into the VAB by the crawler-transporter; where it is positioned on six steel pedestals 22 ft high. Inside the VAB, the two Solid Rocket Boosters (SRBs), External Tank (ET), and Orbiter are assembled as one system. The MLP and its Shuttle Transport System (STS) are then picked-up by the crawler-transporter and slowly moved (Figure B.2-32) to either of the two launch complexes (LC-39A or LC-39B). At the launch complex, the MLP and payload are again lowered onto six steel pedestals where it rests until launch (Figure B.2-40).

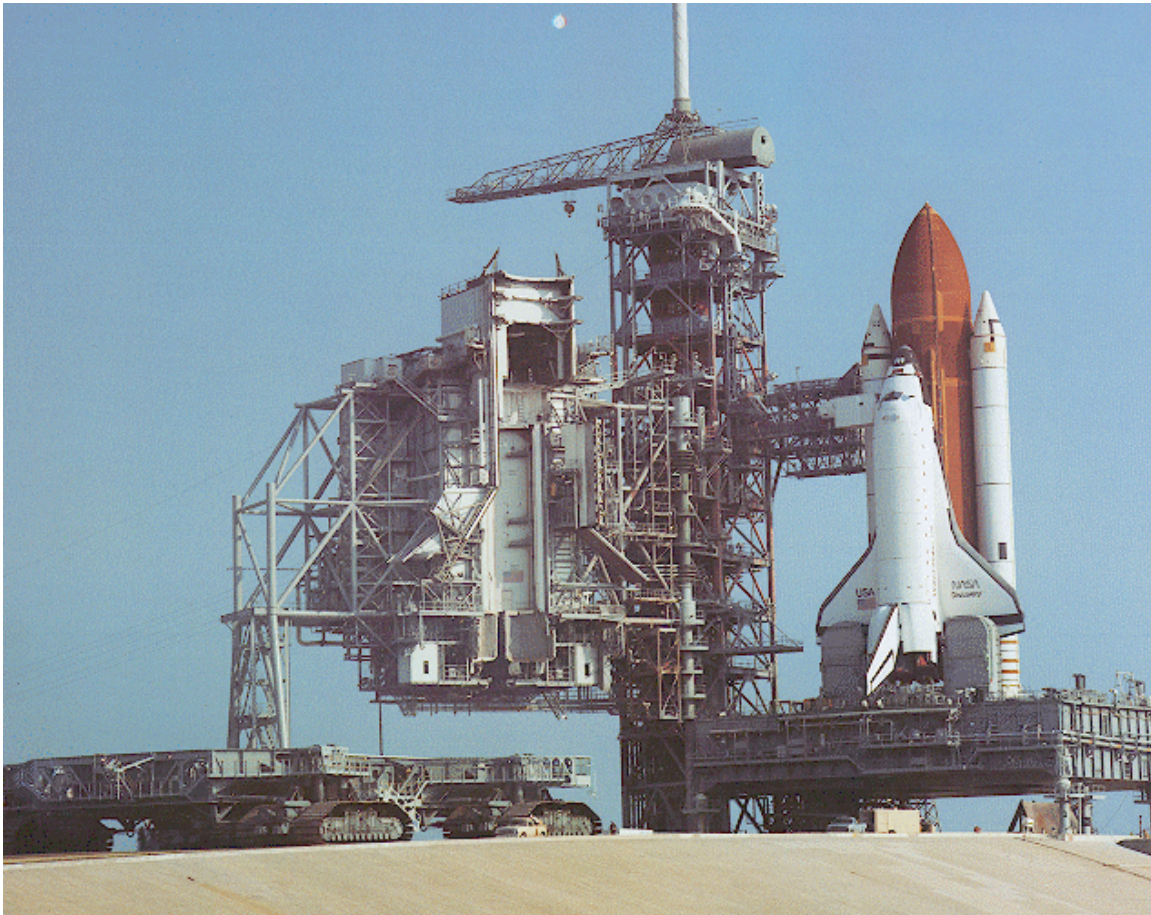


Figure B.2-40 MLP with Shuttle at Launch Pad
(Crawler is backing away to a safe distance)

The three Mobile Launchers used in the Apollo/Saturn operations were modified for use in Shuttle operations. With cranes, umbilical towers, and swing arms removed, the Mobile Launchers were redesignated Mobile Launcher Platforms (MLP). In place of one large opening in the platform, three smaller openings accommodate flames and hot exhaust gases from the solid rocket boosters and the orbiter engines. Segments of the dismantled umbilical towers are part of the permanent installation at the launch pad, where they serve as sections of the Fixed Service Structure (FSS). A third Apollo umbilical tower, removed from MLP-3, has been cut into 20 ft sections and placed in a field in the KSC industrial area (Figure B.2-41). Someday it may be reconstructed as part of the KSC tour route³⁹⁶.



Figure B.2-41 Apollo Umbilical Towers In Storage At KSC

OPF – The Orbiter Processing Facilities are the hangars used to process and house the orbiters after landing and prior to stacking for the next mission. Immediately after landing, the orbiter is towed to the OPF. Upon entering the OPF (Figure B.2-42), the orbiter undergoes safing procedures. This includes removing residual fuels and explosive ordnance items. Then the orbiter's previous mission payloads are removed and the vehicle is fully inspected, tested, and refurbished for its next mission. These functions require approximately two-thirds of the time between missions. The remainder is devoted to the installation and checkout of the payload for the next mission. Power-up testing of orbiter vehicles in the OPF is actually controlled from consoles in the LCC. When the OPF processing is complete, the orbiter is trucked (Figure B.2-43) to the VAB center aisle where it is lifted and stacked with the External Tank and two SRBs.

³⁹⁶ <http://www-pao.ksc.nasa.gov/facilities/mlp.htm>

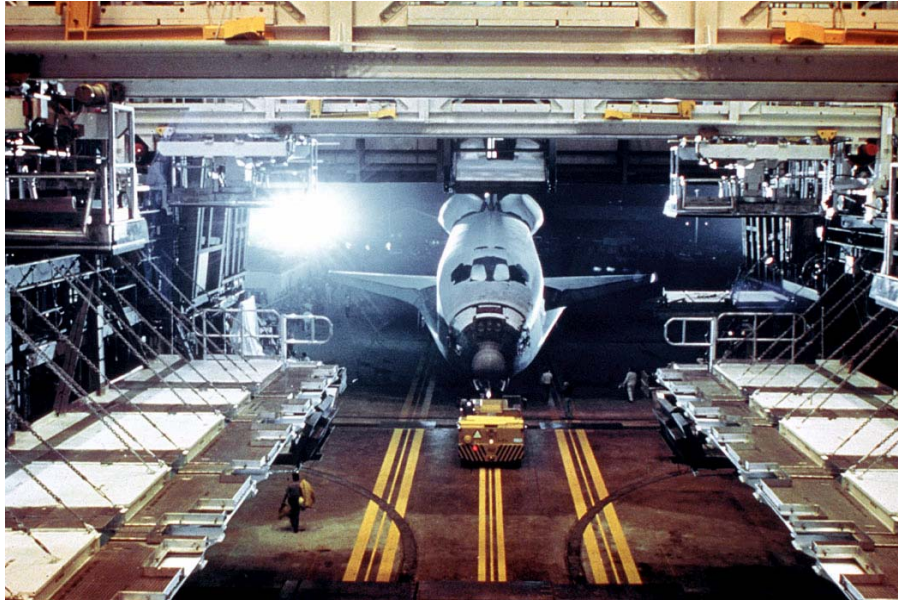


Figure B.2-42 Shuttle Being Towed Into the OPF



Figure B.2-43 Shuttle Leaving OPF-2 For Short Trip To The VAB

There are three OPFs at KSC. OPF-1 and OPF-2 are directly west of the VAB. OPF-3 is located northwest of the VAB. OPF-1 and OPF-2 consist of two 2,700 sq meter (29,000 sq ft) high bays and are separated by a 2,130 sq meter (23,600 sq ft) low bay. OPF-3 is located across the street and is a 4,645 sq meters (50,000 sq ft) facility. It consists of a high bay 29 meters high (95 ft) high and a two-story low bay area.

Recovery Ships – After launch, the Shuttle rolls 90 degrees about a vertical axis and begins to head east or northeast. One hundred seconds into flight, the whole stack weighs less than half of what it did at launch. Approximately two minutes into ascent, the orbiter is 24 miles high and traveling at Mach 4 when the SRBs have depleted their propellant. The SRBs are then jettisoned and at the proper altitude, a small drogue chute is deployed to slow their descent (Figure B.2-44). Then, three main chutes are deployed to ensure a safe splashdown about 140 miles out into the Atlantic. Once down, two NASA recovery ships are waiting to recover the boosters (Figure B.2-45)³⁹⁷.



Figure B.2-44 SRB With Drogue Chute During Descent

The two steel hull ships have sophisticated electronic communication and navigation equipment, including GPS, search radars, collision-avoidance sonars, loran C, VHF and single-side-band high-frequency radio systems, direction finders, fathometers and gyro compasses. Each vessel has a displacement of 1,052 tons. Propulsion is provided by twin

³⁹⁷ <http://www-pao.ksc.nasa.gov/kscpao/visit/kscovrlaurec.htm>

diesel engines with a combined power output of 2,900 horsepower. Maneuvering is provided by a diesel-driven, 425-horsepower bow thruster.

The ships leave their Cape Canaveral Air Station berths at Hangar AF about 24 hours before launch and proceed to the predicted impact site. Traveling at a cruising speed of 10 to 12 knots, they reach the area in about 10 hours. Prior to lift-off, the ships conduct visual and electronic sweeps of the predicted impact area to ensure it is clear. Each ship recovers one SRB casing, three main parachutes, and a frustum-drogue combination. Under optimum sea conditions, booster retrieval operations are completed about five hours and 30 minutes after the launch. The ships then proceed back to Cape Canaveral and up the Banana River to Hangar AF at the Cape Canaveral Air Station³⁹⁸.

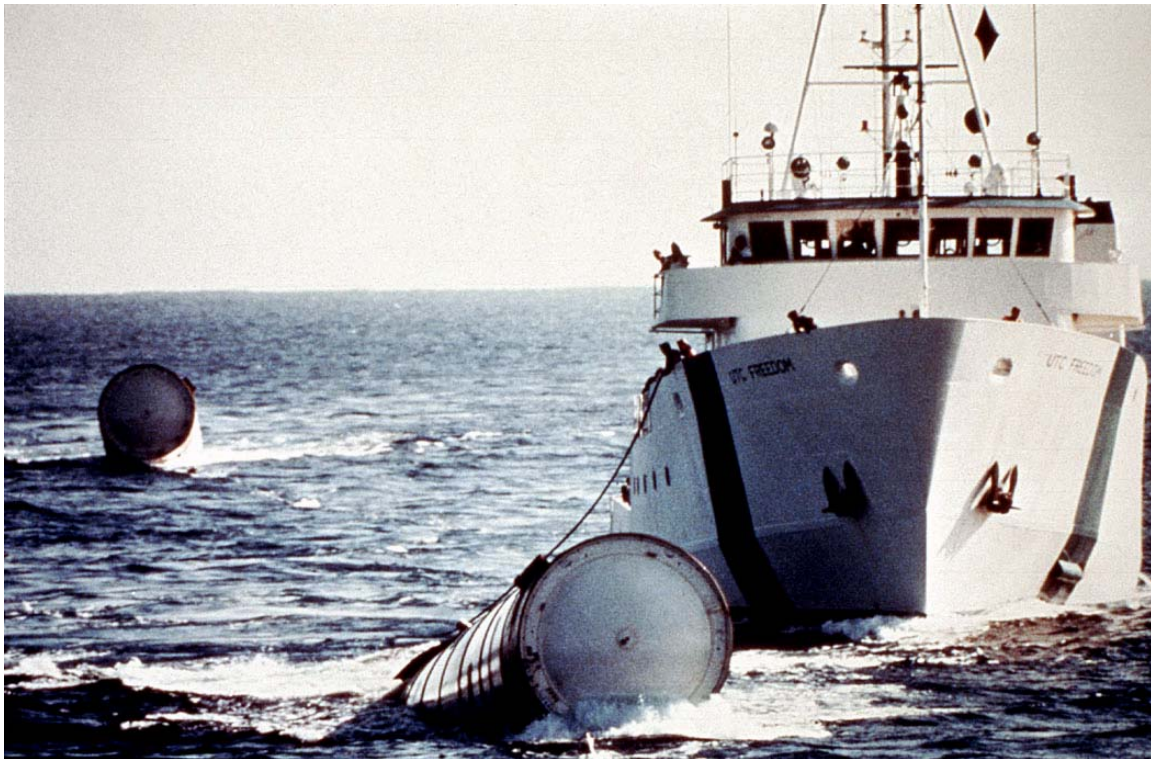


Figure B.2-45 SRB Recovery Ship

SLF – The Shuttle Landing Facility (Figure B.2-46) at KSC has one of the longest runways in the world. The runway is 4,572 meters (15,000 feet) long, 91.4 meters (300 feet) wide and 40.6cm (15 inches) thick at the center. It includes a 305 meters (1,000-foot) paved safety overrun at each end. A paved runway at Edwards Air Force Base in California matches the SLF runway in length and width and has an overrun of 5 miles that extends into a dry lakebed. The SLF was dredged out of the Merritt Island swamps

³⁹⁸ <http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/sts-lcc.html#sts-lcc>

and is located 3.2 km (2 miles) northwest of the VAB. It has a northwest/southeast alignment (330 degrees northwest/150 degrees southeast)³⁹⁹.

The facility also includes a 150 x 168 meter (490 x 550 ft) parking apron, an aircraft hangar facility, and a 3.2 km (2 mile) tow-way connecting it with the Orbiter Processing Facility. Other facilities include the Landing Aids Control Building (LACB) and the Mate/Demate Device (MDD) used to raise and lower the orbiter from its 747 carrier aircraft during ferry operations.



Figure B.2-46 Shuttle Landing Facility (SLF)

The Shuttle Landing Facility is equipped with a number of navigation and landing aids to assist Shuttle pilots in landing. There are four sophisticated Microwave Scanning Beam Landing System (MSBLS) ground stations - two located at each end of the runway - that provide elevation and directional/distance measurement for landing approaches from the northwest (runway 15) or southeast (runway 33). Equipment onboard the orbiter receives the data from the MSBLS stations and automatically makes any needed adjustments to the glide slope.

³⁹⁹ <http://science.ksc.nasa.gov/facilities/slf.html>

SSPF – The Space Station Processing Facility (Figure B.2-47) is a relatively new facility built to support the construction of the International Space Station (Figure B.2-48). The SSPF is located just east of the Operations and Checkout Building at Kennedy Space Center's industrial area. The SSPF was built for processing ISS flight hardware. A three-story building has two processing bays, an airlock, operational control rooms, laboratories, logistics areas, office space, and a cafeteria. The processing areas, airlock, and laboratories were designed to support non-hazardous Station and Shuttle payloads in 100,000 class clean work areas.



Figure B.2-47 Space Station Process Facility (SSPF)



Figure B.2-48 International Space Station (ISS) in June 2002

VAB - The Vehicle Assembly Building (Figure B.2-49) is one of the largest buildings in the world. It was originally built for assembly of Apollo/Saturn vehicles and was later modified to support Space Shuttle operations. Today, High Bays 1 and 3 are used for integration and stacking of the complete Space Shuttle vehicle. High Bay 2 is used for external tank (ET) checkout and storage and as a contingency storage area for orbiters. High Bay 4 is also used for ET checkout and storage, as well as for payload canister operations and solid rocket booster (SRB) contingency handling⁴⁰⁰. The VAB covers 8 acres. It is 525 ft tall, 218 716 ft long and 518 ft wide. It encloses 129,428,000 cubic feet of space. The Low Bay area contains Space Shuttle main engine maintenance and overhaul shops, and serves as a holding area for SRB forward assemblies and aft skirts.



Figure B.2-49 VAB With LCC Off To Right

Visitors Complex – A Visitors Complex⁴⁰¹ (Figure B.2-50) is located on KSC. It includes the following:

⁴⁰⁰ <http://www-pao.ksc.nasa.gov/facilities/vab.htm>

⁴⁰¹ http://www.kennedyspacecenter.com/html/ksc_vc.htm

- Displays & Exhibits
- Saturn 5 building with displays (Figure B.2.51)
- Rocket Garden (Figure B.2-52) featuring many examples of past rockets⁴⁰².
- IMAX movies theaters
- Gift shop (Figure B.2-53)
- Tours of NASA's facilities



Figure B.2-50 KSC Visitor Center

⁴⁰² http://www.kennedyspacecenter.com/html/coming_attractions.html#rg

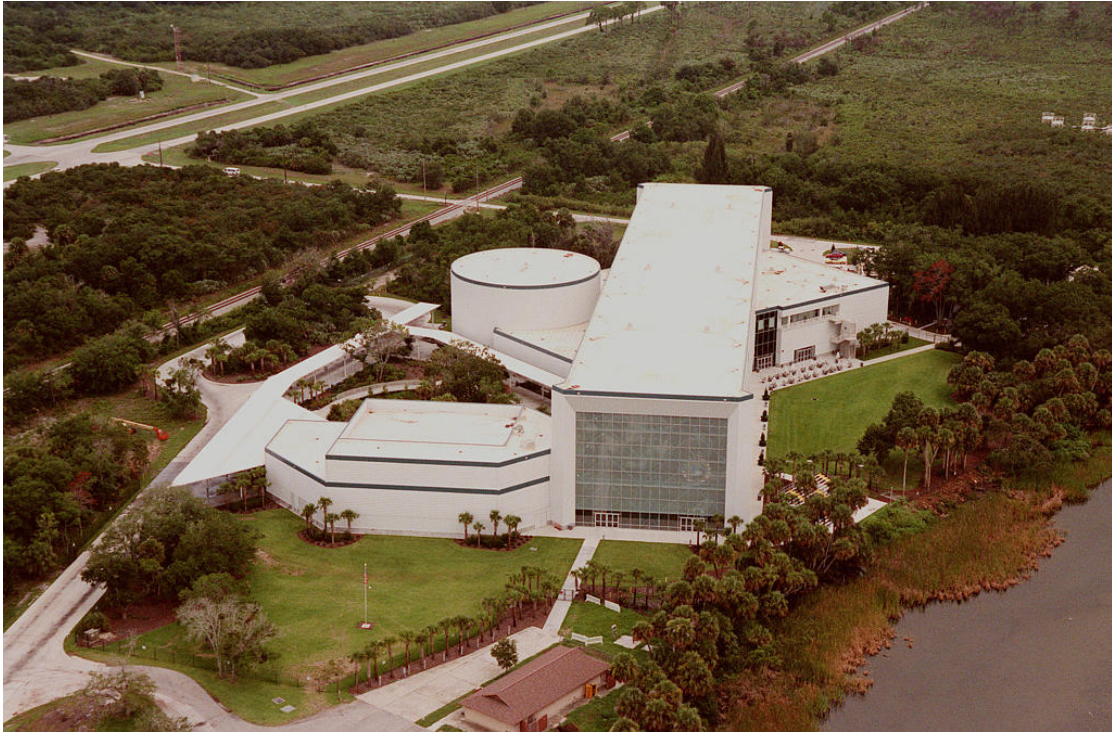


Figure B.2-51 Saturn V Building & Exhibits



Figure B.2-52 Rocket Garden



Figure B.2-53 Gift Shop

Launch Facilities – KSC has two launch facilities on the center. These are LC-39A (Figure B.2-40) and LC-39B. All U.S. manned launches (Figure B.2-54) since December 1968 have occurred from these two facilities. Unmanned NASA launches using expendable vehicles are made from launch complexes (Figures B.2-55) on the Cape Canaveral Air Station. Cape activities were described in the Eastern Range Section of this document. The Cape side plus the KSC side combine to provide over 50 launch complexes. The complexes are numbered 1 through 47 and some of the complexes contain multiple launch pads (i.e. 39A and 39B).



Figure B.2-54 Shuttle Launch From LC-39 A or B



Figure B.2-55 Cape Launch Complexes

Pads 39-A and 39-B are virtually identical and roughly octagonal in shape. The distance between pads is 2,657 meters (8,715 ft). The pad base contains 52,000 cubic meters (68,000 cubic yards) of concrete. The ramp leading up to the pad is inclined at a 5% grade. The flame trench is 13 meters (42 ft) deep, 137 meters (450 ft) long and 18 meters (58 ft) wide. The orbiter flame deflector is 11.6 meters (38 ft) high, 22 meters (72 ft) long and 17.5 meters (57.6 ft) wide. It weights 590,000 kg (1.3 million lbs). The SRB deflector is 12.95 meters (42.5 ft) high, 12.8 meters (42 ft) long and 17.4 meters (57 ft) wide. It weights 499,000 kg (1.1 million lbs). The Sound Suppression Water System is used to protect the launch structure from the intense sound pressure of liftoff. Its water tank is 88.9 meters (290ft) high and has a capacity of 1,135,000 liters (300,000 gallons). Six permanent and four extensible pedestals are used to support the MLP at the pad. Dynamic loads at rebound are 3,175,200 kg (7,000,000 lbs) to 4,762,800 kg (10,500,000 lb) at liftoff. The pad is lit with five clusters of Xenon high-intensity searchlights (total searchlights: 40) around the pad perimeter.

B.2.3 Instrumentation

KSC has the following types of Range instrumentation:

- Radar
- Telemetry
- Optics
- Command Destruct
- Communication
- Weather
- Timing

B.2.3.1 Radar

The Eastern Range has an assortment of launch head and downrange radars to enable precision tracking and range safety throughout the 5000-mile range. Two of these are located at KSC. There are plans to move a third, the Multiple Object Tracking Radar (MOTR) to the KSC property. These are summarized below:

<u>Site</u>	<u>Designation</u>	<u>Type</u>	<u>Band</u>	<u>Dia.-ft</u>	<u>Comments</u>
CCAS	1.39	MOTR	C	12	Figure B.2-56
KSC	19.14	MIPIR	C	29	
KSC	19.17	MCBR	C	12	



Figure B.2-56 Multiple Object Tracking Radar (MOTR)

B.2.3.2 Telemetry

Tel-4 is the Eastern Range’s primary Telemetry site. It is located in the southern part of KSC. Tel-4 has links to all Eastern Range sites, plus communicates with Goddard’s Merritt Island Launch Annex (MILA) located at KSC behind the Visitors Complex. A summary of Telemetry dishes on KSC is as follows:

<u>Site</u>	<u>Telemetry</u>	<u>Dia-Ft</u>	<u>Comments</u>
KSC	TAA-3C	30	Tel-4
KSC	TAA-24A	24	Tel-4

B.2.3.3 Optics

The Eastern Range has one fixed optic site at KSC. In addition, there are various Universal Camera Sites at KSC that accept mobile optic trackers, such as the ATOTS. The fixed site is summarized in Table B.2-2 below:

Table B.2-2 DOAMS Specification

Site Designator	Instrument	Site Location	Lens Focal Length (inches)	Comments
Playalinda Beach	DOAMS	KSC	100 to 400	Canaveral Nat. Seashore

DOAMS - Distant Object Attitude Measurement System (Figure B.2-57) are twin telescope systems combined on a single mount. These are used to track distant objects. An acquisition camera is also mounted with the two telescopes. Three units were obtained from White Sands in the 90's. Two of the units were used to modernize the Cocoa Beach and Playalinda sites. The third unit was used for parts.

**Figure B.2-57 DOAMS**

B.2.3.4 Command Destruct

Command Destruct for the Shuttle is provided by Cape Command and other Range sites. The Shuttle carries explosive ordnances on the solid booster rockets. These are used to terminate their powered flight should a problem arise. The orbiter and external tank do not carry ordnances.

B.2.3.5 Communications

KSC has a communication network consisting of the following:

- Communication Satellites
- Microwave links
- Landlines
- VHF/UHF
- Wireless
- MILA

These are used to support and connect KSC to the Cape, the other Range sites and to the outside World.

Communication Satellites – KSC has a satellite receiver at the Communication Distribution & Switching Center (CD&SC). This link is used for NASA TV and some communications. MILA also contains satellite earth stations for NASA’s TDRSS. These are used for communication with the Shuttle and any experiments using TDRSS.

Microwave Link – The Eastern Range has a two-way Digital Speed-3 microwave link between JDMTA and the XY Building at CCAS with an extension from the XY Building to Tel-4. Communication interfaces are provided at Tel-4, XY building, Patrick AFB, Malabar, and JDMTA. Repeater only stations are located at Stuart, Ft. Pierce, and Wabasso. A second microwave link between MILA and the PDL tracking station 40 miles north at New Smyrna Beach was replaced with a fiber optic link around 2000⁴⁰³.

Landlines – Fiber and copper landlines provide access from CCAS to KSC, within KSC, and to the outside world.

UHF/VHF – Very High Frequency and Ultra High Frequency are used at KSC as follows:

- VHF – Non-military aircraft control
- UHF – Military aircraft, ships, Timing data, PDL voice to Shuttle
- VHF/UHF – Land Mobile Radio (LMR) used by JBOS

Wireless – KSC uses a Telenexus TNEX-2000 in the KSC Operational Intercommunications System (OIC). This is a digital modulation spread spectrum system. It uses a base station, 4 radio/antenna modules and up to 16 remote units with headsets⁴⁰⁴.

MILA – The Merritt Island Launch Annex, operated by NASA’s Goddard Space Flight Center, contains its own unique communication systems. These are as follows⁴⁰⁵:

- Spacecraft Communicating Antennas
 - Two 9-meter (30-foot) diameter S-Band dish antennas used to track moving space vehicles.

⁴⁰³ <http://science.ksc.nasa.gov/facilities/mila/milstor.html>

⁴⁰⁴ [http://technology.nasa.gov/scripts/nls_ax.dll/w3SuccItem\(954\)](http://technology.nasa.gov/scripts/nls_ax.dll/w3SuccItem(954))

⁴⁰⁵ <http://science.ksc.nasa.gov/facilities/mila/milstor.html>

- Two 3-meter (10-foot) diameter dish antennas used primarily to relay data between KSC projects and the Tracking and Data Relay Satellite (TDRS). One antenna, on top of the 140-foot "TDRS Relay" Tower, points to a TDRS user and is connected to the other antenna, which points to the TDRS in stationary orbit.
 - Two UHF tracking antennas, a Teltrac and a Quad Helix, used for voice communication with the Astronauts in the Space Shuttle Orbiter. These antennas are slaved to one of the S-band tracking antennas to point at the Space Shuttle Orbiter during Ascent, Orbit or Landing.
 - Two 1.2-meter (4-foot) diameter dish antennas used by MIL-71 to communicate with Deep Space Network payloads during KSC processing. One antenna is for S-band, the other for X-Band, and they are mounted near the top of the 140-foot "TDRS Relay" tower.
 - A 4.3-meter (15 foot) diameter dish S-band antenna connected whenever a 9-meter antenna is removed from service for refurbishment.
- Support Antennas
 - Two 1.2-meter (4-foot) S-band and a smaller Ku-band antenna on top of the 140 feet high Collimation Tower located about 3/4 mile north of the station. These antennas are used to calibrate/test the steerable antennas.
 - Two stationary Discone UHF Antennas used to monitor the moveable UHF tracking antennas.
 - One Short-Wave Antenna for monitoring the U.S. Bureau of Standards calibrated timing station (WWV from Boulder, Colorado).

B.2.3.6 Weather

KSC weather utilizes resources at KSC and at the CCAS Weather Station. The CCAS Weather Station has a pair of Data General Meteorology System Computers (MSC) that receive, process and store raw data from the ER upper air collection systems (Jimsphere and Meteorological Sounding System (MSS)). The MSCs then transmit processed meteorological profiles to KSC.

KSC weather data is obtained and analyzed using the following⁴⁰⁶:

- Rawinsonde
- Jimsphere
- CGLSS
- Lightning Detection System
- LDAR
- NLDN
- WINDS
- LPLWS

⁴⁰⁶ <http://www-pao.ksc.nasa.gov/kscpao/release/2000/103-00.htm>

- MIDDs
- Weather Surveillance Radar
- Doppler Weather Surveillance Radar
- Doppler Radar Wind Profiler
- Weather Reconnaissance Aircraft
- Rocketsonde
- Satellite Images and Data
- Buoys
- Ships

Rawinsonde - A balloon with a tethered instrument package that radios its altitude to the ground together with temperature, dew point and humidity, wind speed and direction, and pressure data. Rawinsondes reach altitudes exceeding 100,000 feet.

Jimsphere – Jimsphere is a NASA developed, constant volume balloon with 398 conical extensions that create drag and stabilize the balloon (Figure B.2-58⁴⁰⁷). The balloon and extensions are fabricated from Mylar. They are tracked using radar, which provides highly accurate information on wind speed and wind direction up to 60,000 feet.

CGLSS – The Cloud to Ground Lightning Surveillance System is a lightning detection system to record cloud-to-ground lightning strikes in the vicinity of KSC and CCAS. The system includes six Advanced Lightning Direction Finders (ALDF) (Figure B.2-59), each with its own GPS.



Figure B.2-58 **Jimsphere Weather Balloon**

⁴⁰⁷ <http://www.sti.nasa.gov/tto/spinoff1996/48.html>



Figure B.2-59 ALDF

Lightning Detection System - Detects and plots cloud to ground lightning strikes within 125 nautical miles of the Kennedy Space Center. Location accuracy is optimum within 30 nautical miles. Locations of strikes are color coded according to time of occurrence.

LDAR – The Lightning Detection and Ranging was developed by NASA at the Kennedy Space Center. LDAR plots intra-cloud, cloud to cloud and cloud to ground lightning in three dimensions within 100 nautical miles of the Kennedy Space Center. Location accuracy is very high within 25 nautical miles. LDAR data is important in determining the beginning and end of lightning conditions.

NLDN – The National Lightning Detection Network is a commercial data service that plots cloud to ground lightning nationwide. It is used to help ensure safe transit of the Space Shuttle orbiter atop the Shuttle Carrier Aircraft between Edwards Air Force Base in California and the Kennedy Space Center in Florida. It is also used to assess lightning beyond the 125-mile range of the Lightning Detection System.

WINDS (Towers) – The Weather Information Network Display System is an array of 44-instrumented meteorological towers (Figure B.2-60) at CCAS, KSC and surrounding areas. These provide near surface measurements of temperature, dew point, wind direction and wind speed. The towers cover the area in and around Kennedy Space Center and Cape Canaveral Air Station, and are spaced an average of 2.5 - 4 mi. apart. There are two each at LC-39A and LC-39B and three at the Shuttle Landing Facility. The 60-foot towers at the launch pads and the 33-foot towers at the Shuttle Landing Facility are closely monitored for launch and landing criteria. In addition, on the mainland, there is a network of wind towers which extend outward an additional twenty miles. Tower data is an important short-term forecasting tool and also helps determine the direction and distance of toxic corridors in the event of a mishap.

LPLWS (Field Mill) – The Launch Pad Lightning Warning System consists of 31 advanced electric field mill sensors (Figure B.2-61) located throughout KSC and CCAS.

These provide data on lightning activity and surface electric fields induced by charge aloft. They are connected to a computer and display. This data helps forecasters determine when electric charge aloft may be sufficient to create triggered lightning during launch, and to determine when to issue and cancel lightning advisories and warnings.

MIDDS – The Meteorological Interactive Data Display System is the primary data collection, management and display tool used by the 45th Weather Squadron (45 WS) to provide weather analysis, forecast and warning support to the ER and KSC. It integrates diverse weather data on a single display terminal-- satellite images, radar, computer generated graphics of surface and upper air map features, numerical weather models, current weather observations, data from meteorological towers, lightning strikes and field mill information.



Figure B.2-60 **Weather Tower**



Figure B.2-61 Typical Field Mill

Weather Surveillance Radar – This commercial-off-the-shelf radar is located on Headquarters building at Patrick AFB with the processing and display located at the ROCC. Launch forecasters located at Cape Canaveral Air Station and landing forecasters located in Houston can access displays from two different radars. One is located at Patrick Air Force Base south of Cocoa Beach. The other is located in Melbourne at the National Weather Service and is a NEXRAD Doppler radar. Each radar provides rain intensity and cloud top information out to a distance as far as 200 nautical miles.

Doppler Weather Surveillance Radar – A NEXRAD Doppler weather radar is located adjacent to the Melbourne Airport about 40 miles south of CCAS. This radar is owned and operated by the National Weather Service. The NEXRAD radar can provide estimates of total rainfall and radial wind velocities. The ER uses this as a backup to its weather radar at Patrick AFB. CCAS has a feed from the Melbourne site.

Doppler Radar Wind Profiler: Measures upper level wind speed and direction over Kennedy Space Center from approximately 10,000 feet to 60,000 feet. The data, received every 5 minutes, is used to ensure the upper winds used to calculate wind loads on the shuttle vehicle have not significantly changed between balloon soundings. If data from the Doppler Radar Wind Profiler indicates a possible significant change, another Jimsphere balloon is released

Weather Reconnaissance Aircraft – Aircraft are deployed during all Shuttle and expendable launches to make in-situ observations of local weather. Aircraft include a T-38, Shuttle Training Aircraft, and a Learjet 35.

Rocketsonde - A 12-foot-tall instrumented rocket is launched on Shuttle L-1 day that senses and transmits data on temperature, wind speed and direction, wind shear, pressure, and air density at altitudes between 65,000 feet and 370,000 feet. A four-inch in diameter solid rocket motor separates at an altitude of about 5,000 feet, after which an "instrumented dart" coasts to apogee.

Satellite Images and Data - Provided directly to the satellite terminal at USAF Range Weather Operations and NOAA National Weather Service Space Flight Meteorology Group in Houston by the geostationary GOES weather satellites. In addition high resolution images are received from spacecraft in low earth orbit including both the NOAA and the Defense Meteorological Support Program (DMSP) polar orbiting satellites.

Buoys - Meteorological buoys are anchored 20, 110 and 160 nautical miles east-northeast of Cape Canaveral. These buoys relay hourly measurements via satellite of temperature, wind speed and direction, barometric pressure, precipitation, sea water temperature, and wave height and period. Buoy data is used for launch, landing, booster retrieval, and daily ground processing forecasts for the Kennedy Space Center and Cape Canaveral Air Station.

Solid Rocket Booster Retrieval Ships - These vessels radio observed weather conditions and sea state from the booster impact area located up to 150 nautical miles downrange.

B.2.3.7 Timing

KSC Timing is controlled by the Central GPS timing. Timing is received by multiple inputs, including:

LCC: UHF Range Timing from CCAS
Loran 2000C
Loran 2100

VAB Dual GPS receivers

The multiple sources are constantly compared for errors. ER central timing located in the ROCC at CCAS is the reference source for all timing signals transmitter on the ER.

The Shuttle uses a master timing unit, which is a stable crystal-controlled timing source for the orbiter. It sends serial time reference signals to the onboard computers, payloads and various time display panels. It also provides synchronization for instrumentation payloads and other systems⁴⁰⁸.

⁴⁰⁸ <http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/sts-inst.html#sts-inst>

B.3 WESTERN RANGE

B.3.1 Background

B.3.1.1 General

Located on the Pacific Coast about 150 miles north of Los Angeles, Vandenberg AFB is headquarters for the Western Range (Figure B.3-1)⁴⁰⁹. It primarily launches unmanned government and commercial satellites into polar orbits. Vandenberg also tests intercontinental ballistic missiles by launching them into the Pacific Ocean, with splashdown usually occurring at the Kwajalein Atoll within the Marshall Islands.

The Western Range has land-based facilities at the following locations⁴¹⁰:

- Anderson Peak (Monterey County, Ca)
- Pillar Point AFS (San Mateo County, Ca)
- Santa Ynez Peak (Santa Barbara County),
- Vandenberg AFB

The Western Range often uses resources from other ranges to carryout its missions. These include:

- The Pacific Missile Range Facility⁴¹¹ (PMRF) in Hawaii
- Reagan Test Site - Kwajalein, Marshall Island⁴¹² (Army)
- Point Mugu (Navy)
- Laguna Peak (Navy)
- San Nicholas Island (Navy)
- White Sands Missile Range (Army)
- China Lake (Navy)

In addition, mobile assets are sometimes utilized. These include the following:

- Navy NP3D based at Pt. Mugu
- *Air Force ARIA (Advanced Range Instrumentation Aircraft) at Edwards*

⁴⁰⁹ http://www.vandenberg.af.mil/30sw/history/tanks_to_missiles/lineage/history_and_lineage.html

⁴¹⁰ <http://www.acq.osd.mil/te/mrtfb/commercial/sw30/wspace.html>

⁴¹¹ <http://www.acq.osd.mil/te/pubfac/pmrf.html>

⁴¹² <http://www.smcd.army.mil/kmr.html>

The Vandenberg area is ideally oriented for missile launches. The northern portion has a coastline facing west and the southern portion has significant coastline facing south. This unique geography permits launch azimuths ranging from 154 to 280 degrees, enabling over-ocean ballistic and polar space launches. Vandenberg is the only location in the continental United States permitting polar orbit spacecraft launches without over-flying any land mass.

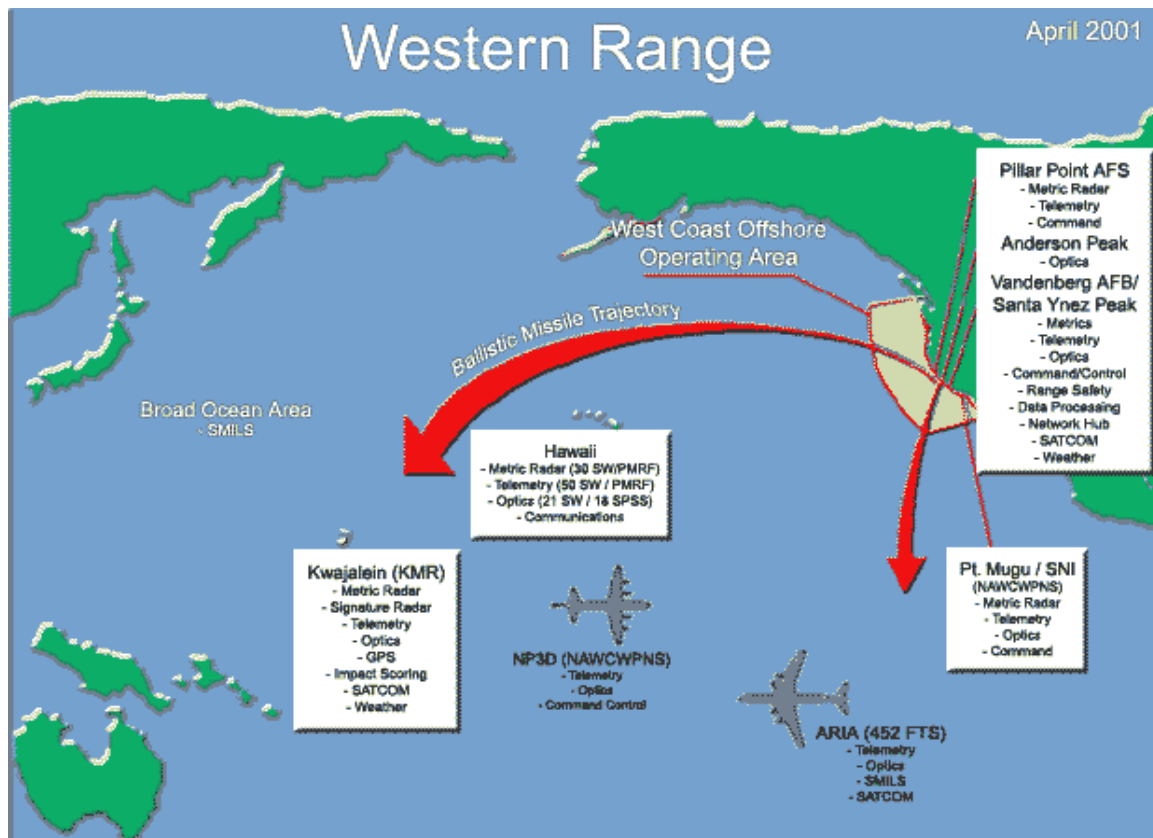


Figure B.3-1 Western Range

The Air Force Space Command's 30th Space Wing operates the Western Range. The 30th Space Wing is comprised of four main groups⁴¹³. These are

- 30th Operations Group
- 30th Logistics Group
- 30th Medical Group
- 30th Support Group

The 30th Operations Group operates the Western Range and conducts space and missile launch operations. The Western Range is a vast tracking, telemetry and command

⁴¹³ http://www.vandenberg.af.mil/Templates/fact_sheet/index.html

complex that begins along Vandenberg's California coastline and extends westward across the Pacific Ocean. The range consists of electronic and optical tracking systems located along the Pacific Coast that collect and process launch-related data. The 2nd Space Launch Squadron is responsible for all space lift operations.

The 30th Support Group provides support services to Vandenberg AFB.

The 30th Medical Group provides medical, dental, bio-environmental, and public health services for people assigned to Vandenberg Air Force Base, their families, and retirees in the local area.

The 30th Logistics Group provides supply, contracting, communication and transportation support for 30th Space Wing launch missions.

Major units at Vandenberg include: 14th Air Force, 576th Flight Test Squadron, 381st Training Group, and Detachment 9 of the Space and Missile Systems Center

B.3.1.2 History

In 1941, 86,000 acres of open cattle grazing land was transferred to the United States Army and transformed almost overnight into Camp Cooke; a training center for armored and infantry troops. It later added a POW camp and a military prison. After WW-II, there was a short period of inactivity before it was called up again for the Korean War. Following the Korean War, most of the area again reverted to cattle and sheep grazing.⁴¹⁴ The prison facilities remained active and were the installation caretakers.

The present day Vandenberg facility is made up of three tracts of land acquired over a decade.

North Tract - In November of 1956, 64,000 acres of North Camp Cooke (Figure B.3-2) were transferred to the Air Force, per the directions of Secretary of Defense, Charles E. Wilson, for use as a missile launch and training base. Its coastal setting and remote location made the site ideal for launching intermediate range ballistic missiles to targets in the Pacific Ocean. Its geographic features also enabled polar orbit satellite launches without over flight of populated landmasses. The remaining 19,800 acres of Camp Cooke were transferred to the Navy as part of their Pacific Missile Range at Point Mugu. This Navy section of Camp Cooke became known as the Naval Missile Facility at Point Arguello.

⁴¹⁴ <http://www.vandenberg.af.mil/30sw/history/index.html>

Middle Tract – On November 16, 1963, Secretary of Defense Robert McNamara ordered a restructuring that including transferring the Navy’s Point Anguello section to the Air Force. This increased Vandenberg’s area to 84,000 acres⁴¹⁵.

Southern Tract – On March 1, 1966, the Air Force started land acquisition for the 15,000 acres south of the Point Anquello. This land was owned by the Sudden Ranch and eventually was annexed through eminent domain with the courts establishing the sale price (\$9M). This last parcel of land was acquired to accommodate SLC-6 and the proposed Manned Orbiting Laboratory program.

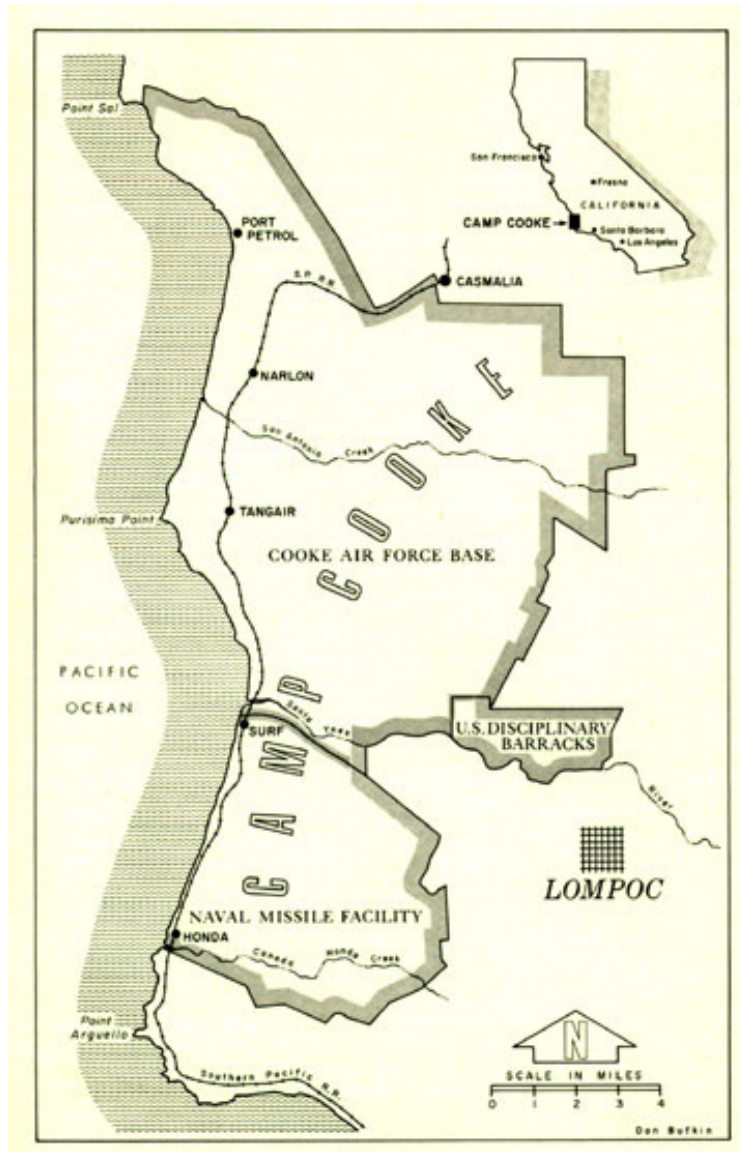


Figure B.3-2 Camp Cooke Divided Between Air Force & Navy

⁴¹⁵ http://www.vandenberg.af.mil/30sw/history/tanks_to_missiles/land_acq/land_acquisitions.html

The Air Force's 6591st Support Squadron was established at Cooke in January 1957. Construction began in April of that year. The official ground breaking ceremonies for the future missile base were held on May 8, 1957. The prison facilities were transferred to the U.S. Bureau of Prisons in August 1959. Today, the prison is known as the U.S. Penitentiary at Lumpoc.

In October 1957, Russia launched its Sputnik satellite and sent shockwaves throughout the non-Communist world. The Air Force responded by accelerating its missile program development. Management for Cooke AFB was transferred from Air Research and Development Command (ARDC) to the Strategic Air Command (SAC) on January 1, 1958. On October 4, 1958, Cooke AFB was renamed Vandenberg AFB in honor of General Hoyt S. Vandenberg, the Air Force's second Chief of Staff.⁴¹⁶ The first launch from Vandenberg AFB occurred on December 16, 1958. The following year, February 28, 1959, the world's first polar orbiting satellite was successfully launched. This Corona satellite was the US's first photo reconnaissance satellite.

The following is a summary of some of the missile programs at Vandenberg:

Thor	12/16/58
Atlas	9/9/59
Titan I	1961
Titan II	unknown
Minuteman	unknown
Peacekeeper ICBM	6/83
Titan IV	3/91
Pegasus	4/95
Delta II	2/96
Atlas II AS	12/99

In 1965, the Air Force Western Test Range (AFWTR) was given full responsibility for ICBM and space support functions previously assigned to the Navy's Pacific Missile Range at Point Mugu. This involved the transfer of fixed and mobile sites at Point Arguello, Ca.; Pill Point, Ca.; Kokee Park, Hawaii; Canton, Midway; Wake Island, Eniwetok and Bikini Atolls in the Marshall Islands; and six each range instrumentation ships. By 1968, range instrumentation ships had peaked at eleven. In January 1975, the last AFWTR ship (USNS Sunnyvale) was decommissioned.

In the 60's, Vandenberg was selected by the Air Force for the Manned Orbiting Laboratory (MOL). The MOL was designed to be launched by a Titan III booster carrying a modified Gemini B capsule attached to a space laboratory. Construction on Space Launch Complex 6 (SLC-6) began in March 1966. It was canceled by President Richard Nixon in June 1969 due to the Vietnam War, cost overruns, and other issues.

⁴¹⁶ http://www.vandenberg.af.mil/30sw/history/tanks_to_missiles/af_takes_charge/

On October 1, 1990, the Western Space and Missile Center (WSMC) was transferred from Air Force Systems Command to Air Force Space Command. On November 19 1991, WSMC was redesignated the 30th Space Wing. On January 15, 2002, host base responsibilities for Vandenberg were transferred from the Strategic Air Command to Air Force Space Command.

Today, the mission of the 30th Space Wing is to:

- Manage and support space lift operations
- Support flight tests of the nation's intercontinental ballistic missile force
- Operate the Western Range network, consisting of instrumentation sites along the California coast and downrange in the Hawaiian Islands, used by the U.S. Government and commercial launch firms operating space, missile, and aeronautical vehicles from Vandenberg.
- Provide host base support services for the Vandenberg AFB community. As of December 2000, the wing consisted of approximately 2,463 (1,620 military and 843 civilians).⁴¹⁷

B.3.2 Facilities

B.3.2.1 General

Vandenberg is a large base with the normal assortment of base facilities.

Major services include:

- Weather Squadron providing
 - Forecasting
 - Surface and upper-air observing
 - Resource protection from severe weather and toxic hazards
- 76th Helicopter Flight operations with five UH-1N helicopters providing
 - Safety and security operations for range operations
 - Aerial photography
 - Wildfire fighting, search and rescue, medical evacuation
 - Flight hardware recovery
 - Security, search, and rescue support for NASA Space Shuttle operations at Edwards AFB
- 30th Operations Support Squadron
 - Manages 30th Space Wing SpaceLift operations training programs
 - Manages air-field operations
 - Provides intelligence services for the wing and tenant units

⁴¹⁷ http://www.vandenberg.af.mil/30sw/history/tanks_to_missiles/lineage/history_and_lineage.html

- Operates the Training Device Design and Engineering Center
- Prepares and executes all host base support for AFSPC's annual Guardian Challenge competition, Guardian Tiger and Guardian Sword readiness programs
- Air Field – Vandenberg AFB has the longest runway in the country⁴¹⁸

B.3.2.2 Launch

Vandenberg provides the buildings, facilities and equipment essential for missile and spacecraft operations. Facilities include launch vehicle and payload assembly buildings; launch complexes, and post-launch operation facilities.

SLC-2W – Space Launch Complex #2 West is used for Boeing Delta-II (Figure B.3-3)⁴¹⁹ launches. Two-stage Delta II rockets typically fly LEO missions, while three-stage vehicles typically deliver payloads to GTO, or are used for deep space explorations.

SLC-3E – SLC-3E is used for Atlas-II AS launches (Figure B.3-4)

SLC-4W – SLC-4W is used for Titan II (Figure B.3-5) launches. The Titan II launchers are refurbished deactivated Titan II intercontinental ballistic missiles (ICBMs) converted by Lockheed Martin for use as space launch vehicles. The company was contracted in 1986 to refurbish, integrate, and launch 14 Titan II ICBMs for government space launch requirements. Conversion involves modifying the forward structure of the second stage to accommodate a payload; manufacturing a new 10-ft diameter payload fairing with variable lengths plus payload adapters; refurbishing the Titan's liquid rocket engines; upgrading the inertial guidance system; developing command, destruct, and telemetry systems; and performing payload integration⁴²⁰.

⁴¹⁸ http://www.vandenberg.af.mil/30sw/organizations/30og/30oss/airfield_ops/index.html

⁴¹⁹ <http://www.boeing.com/defense-space/space/delta/delta2/delta2.htm>

⁴²⁰ http://www.ast.lmco.com/launch_titanIIfacts.shtml



Figure B.3-3 Delta Launch



Figure B.3-4 Atlas Ready For Launch



Figure B.3-5 Titan II Being Prepared For Launch

SLC-4E – SLC-4E is used for Titan IV (Figure B.3-6) launches. This heavy lift vehicle is capable of placing 47,800 pounds into low-Earth orbit or more than 12,700 pounds into geosynchronous orbit– (22,300 miles).



Figure B.3-6 Titan IV Launch From Vandenberg

SLC-6 – SLC-6 (Figure B.3-7) is the most famous launch complex at Vandenberg AFB. It was initially built for the Manned Orbiting Laboratory (MOL). After the MOL program was cancelled in 1969, SLC-6 was basically abandoned for nearly a decade. In 1979, SLC-6 was reactivated and underwent an estimated \$4 billion modification program in preparation for use by the Space Shuttle program. Following the Challenger accident in 1986 and after a joint decision by the Air Force and NASA, SLC-6 was again abandoned. Today, SLC-6 has been modified for use with the Delta IV.⁴²¹



Figure B.3-7 SLC-6 in 1986

Peacekeeper – Special launch facilities are used for testing the silo-staged Peacekeeper missiles.

⁴²¹ http://www.vandenberg.af.mil/30sw/history/tanks_to_missiles/launch%20programs/index.htm

Minuteman III – Special launch facilities are used for testing the silo-staged Minuteman III (Figure B.3-8).

Airborne – Western Range facilities are sometimes used for air launches of Orbital Sciences’ Pegasus missile from their converted L-1011.



Figure B.3-8 Minuteman III Launch

B.3.3 Instrumentation

B.3.3.1 Locations

Western Range key instrumentation is located at the following sites:

- Anderson Peak (Monterey County, CA)
- Pillar Point AFS (San Mateo County, CA)
- Santa Ynez Peak (Santa Barbara County, CA)
- Vandenberg AFB

Additional instrumentation capability is provided by the Navy at Point Mugu, the Pacific Missile Range Facility, and by the Army at Reagan Test Site (Kwajalein) to support missions.

Anderson Peak

Anderson Peak, located 150 miles north of Vandenberg, contains long-range optic equipment.

Pillar Point

Pillar Point (Figure B.3-9)⁴²² is located on the Pacific Coast just south of San Francisco. It contains metric radar, telemetry, and command instrumentation. The 80-ft TAA-8 telemetry antenna shown in the figure below was later removed.



Figure B.3-9 Pillar Point Instrumentation Site

Santa Ynez Peak

Santa Ynez Peak is located 30 miles southeast of Vandenberg. It contains radar, telemetry, and optic instrumentation.

Vandenberg

Vandenberg AFB contains radar, telemetry, and command.

⁴²² <http://geoimages.berkeley.edu/GeoImages/SemansAir/AirPhotos/PILPOINT.JPG>

B.3.3.2 Equipment

Range instrumentation includes the following:

- Radar
- Telemetry
- Command
- Optic

Radar

AN/FPQ, TPQ, and FPS radars at Vandenberg and Pillar Point provide precision tracking. Supporting radars at Kaena Point (Hawaii), Point Mugu (California), and Reagan Test Site (Kwajalein) often provide supplemental trajectory data for range safety, flight analysis, and aircraft operations.

Telemetry

Receiving and recording stations at Vandenberg AFB and Pillar Point, with their associated antennas; acquire, record, and transmit telemetry data to the Vandenberg AFB data processing equipment through fiber optics and microwave data transmission systems. The display areas are capable of providing real-time computation, quick-look displays, and post-data listings⁴²³.

Command

Command destruct transmitters, used to destroy errant missiles or space boosters, are located at five sites -- three at Vandenberg AFB, one at Pillar Point, and one at a Navy site at Laguna Peak, near Point Mugu.

Optics

Three large-aperture long range telescopes are situated on coastal mountains; one on Vandenberg AFB, one 150 miles north on Anderson Peak, and one 30 miles southeast by Santa Ynez Peak.

Midcourse Operations Support

The metric radar at Kaena Point, HI provides midcourse data on ballistic missile flights and supports Space Transportation System (shuttle) and other on-orbit operations. Additional support is available from the Maui long-range optical site; Navy operated telemetry and radar systems, and the AFSPACECOM⁴²⁴ Hawaiian Tracking Station.

⁴²³ <http://www.acq.osd.mil/te/mrtfb/commercial/sw30/wspace.html>

⁴²⁴ <http://www.spacecom.af.mil/hqafspc/>

B.4 WALLOPS FLIGHT FACILITY

B.4.1 Background

B.4.1.1 General

Wallops Flight Facility is NASA's primary facility for sub-orbital programs.⁴²⁵ It also supports orbital launches. To date, Wallops Flight Facility has launched over 14,000 rockets as part of its research programs. Wallops Flight Facility has been heavily involved in the manned space program and supports northbound launches on the Eastern Range.

B.4.1.2 History

The Wallops Flight Facility was established in 1945 under NASA's predecessor, the National Advisory Committee for Aeronautics (NACA). It was built to utilize rockets for aeronautical research. Its first rocket launch was on July 4, 1945.

From 1945 to 1957, the Wallops Flight Facility was called the Pilotless Aircraft Research Station and specialized in aerodynamic and heat transfer research.

In 1958, it was renamed Wallops Station and supported the manned space program with research in re-entry and life-support systems (Figure B.4-1). Wallops Flight Facility has supported Project Mercury, Project Apollo, Project Gemini and Space Shuttle missions.



Figure B.4-1 Capsule Escape Rocket Testing

⁴²⁵ http://www.wff.nasa.gov/pages/wallops_history.html

In 1975, Wallops Flight Facility went through yet another name change to become Wallops Flight Center. Research continued with suborbital rockets and was expanded to include aircraft noise reduction studies.

In 1982, the facility at Wallops was renamed to today's Wallops Flight Facility, and was consolidated with Goddard Space Flight Center (GSFC). Its customer base became more diversified with more commercial users for the research airport, tracking facilities and launch range. Wallops Flight Facility continues to support academic and government research programs using sounding rockets, balloons and scientific aircraft.

B.4.1.3 Present Mission

Today, Wallops Flight Facility's typical workload is⁴²⁶:

- 30 sounding rockets per year
- 35 scientific balloon launches per year
- 500 aircraft flight hours on scientific payloads

Wallops Flight Facility's mission consists of:

- Management of NASA's Sounding Rocket Program (Figure B.4-2)
- Management of NASA's Balloon Program (Figure B.4-3), including development of an Ultra Long Duration Balloon Project
- Operations, maintenance and sustaining engineering efforts for the Orbital Tracking Program
- Management, maintenance and operation of scientific aircraft
- Continued responsibility for theoretical and experimental research related to the broad study of Earth science and global change
- Responsibility for NASA's Small Shuttle Payload Projects including SPARTAN, SPARTAN Lite, the Hitchhiker series (Hitchhiker, Hitchhiker, Jr., Get-Away Specials and Space Experiment Module) and the University Class Explorer Program
- Maintenance and operation of Wallops launch range, aeronautical research airport and associated tracking, data acquisition and control instrumentation systems.

⁴²⁶ <http://www.wff.nasa.gov/mission2000/pages/suborbital.html>



Figure B.4-2 Wallops Scientific Rocket



Figure B.4-3 Wallops Scientific Balloon

B.4.2 Facilities

Wallops Flight Facility is located on the Atlantic coast of northeastern Virginia. It is accessible from Virginia only through Newport News. It is also accessible from Maryland. The Wallops Flight Facility is spread out over three land areas, as shown in Figure B.4-4.

These are

- Main Base (Figure B.4-5)
- Island (Figure B.4-6)
- Mainland

Today, Wallops Flight Facility includes the following primary facilities:

- 6 launch pads
- Assembly facilities
- Range Control Center
- Tracking and Data Acquisition
- Blockhouses
- Hazardous Storage
- Research Airport
- Virginia Commercial Space Flight Authority

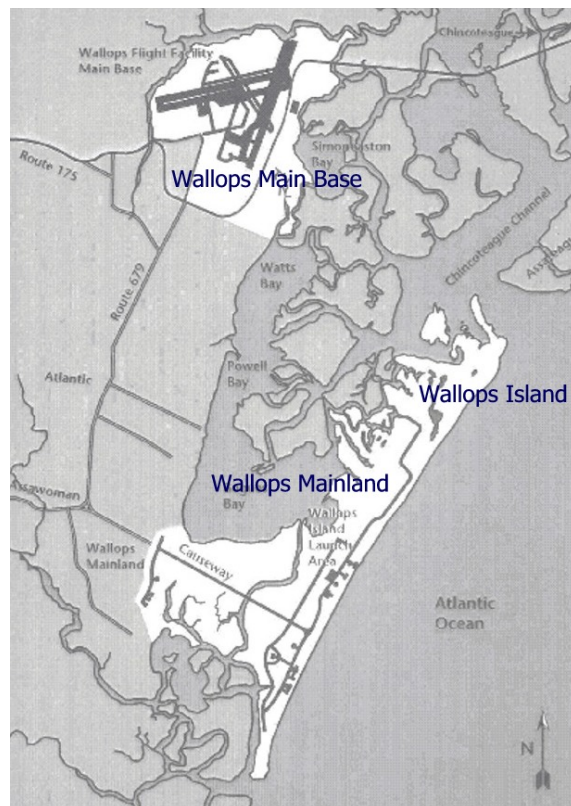


Figure B.4-4 Wallops Three Main Sites



Figure B.4-5 Wallops Main Base



Figure B.4-6 Wallops Launch Facilities

B.4.3 Instrumentation

Wallops Flight Facility instrumentation includes the following⁴²⁷:

- Telemetry
- Radar (Figure B.4-7)
- UHF transmitters & Range Safety systems
- Film/video tracking
- Communications
- Weather

Wallops Flight Facility radars often provide support for the Eastern Range during launches with northern trajectories. The following radars are available at Wallops Flight Facility:

<u>Radar Design</u>	<u>Designation</u>
AN/FPQ-6	86.18
AN/FPS-16s	86.16I
AN/FPS-16s	86.16R



Figure B.4-7 Wallops FPQ-6 Radar

In addition, Wallops Flight Facility has mobile launch facilities that are offered as a service to other ranges. Wallops Flight Facility has provided support at Argentia for the Eastern Range and at Cordova, AK for the Kodiak launch facility.

⁴²⁷ http://www.wff.nasa.gov/vtour/pages/wff_vt_p23x.htm

B.5 REAGAN TEST SITE (KWAJALEIN)

B.5.1 Background

B.5.1.1 General

The Reagan Test Site (RTS) is centered at the Kwajalein Atoll in the Republic of the Marshall Islands (RMI). Kwajalein is approximately 4,800 miles southwest of California and 2,500 miles southwest of Hawaii. It contains the world's largest lagoon. While RMI has over 750,000 square miles of territory, it contains only 69.8 square miles of landmass, equivalent to an area about the size of Washington D. C. Figures B.5-1 and B.5-2 show the location of the Kwajalein Atoll and its main island.⁴²⁸

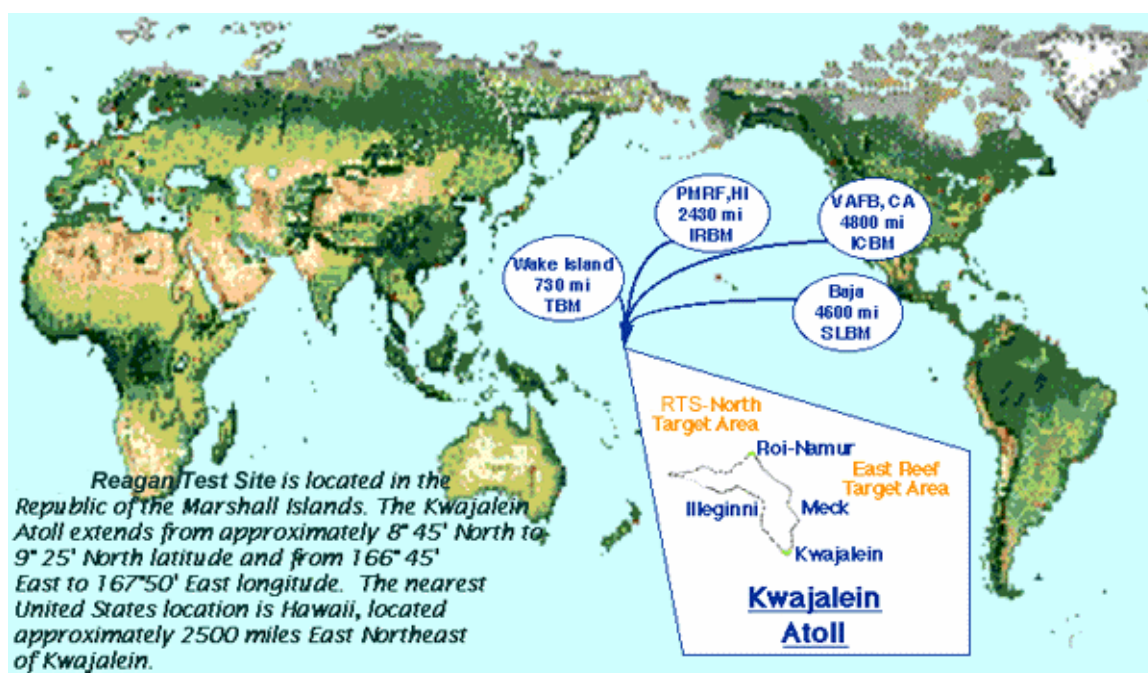


Figure B.5-1 Kwajalein Atoll

Kwajalein is an independent range, operated by the U.S. Army. It contains its own launch site. RTS possesses the only treaty-approved launch site from which the United States can test, due to extended flight distances, "operational" Strategic ABM interceptor missiles. The Meck Island site is used multiple times each year for interceptor testing. In the 1950's, Nike-Zeus missiles were launched as ICBM interceptors. In March of 1968, the Spartan missile was successfully launched and later the Sprint missiles were launched. In later years, testing associated with the Strategic Defense Initiative (SDI) was conducted at Kwajalein. Kwajalein was renamed the Ronald Reagan Test Site (RTS) in 2001. It is often used in conjunction with the Western Range for scoring ICBM performance. Today, a new generation of anti-ballistic missile testing continues.

⁴²⁸ http://www.smdc.army.mil/kwaj/KMR_LOCN.HTM



Figure B.5-2 Kwajalein Island

Kwajalein is also used for monitoring Russian ICBM tests in the Pacific, monitoring new foreign launches, and scoring ICBM launches from the Western Range.

B.5.1.2 History

Prior to WW-II, Kwajalein was visited or occupied by the Spanish, British, Russians and Germans. In 1914, it was claimed by Japan. In February 1942, Kwajalein was the target of the first aircraft carrier offensive launched by the US against Japan, in what became the first victories for the US after the December 7, 1941 attack on Pearl Harbor. After WW-II, the US continued to maintain its presence on the island. In 1946, Kwajalein supported US atomic testing, codenamed Operation Crossroads, at nearby Bikini. Kwajalein continued to figure prominently in atomic testing during Operations Sandstone, Greenhouse, and Ivy at nearby Enewetak from 1948 through 1952. Around 1958, the US selected Kwajalein as the site of a test facility for an ICBM intercept program. Roi-Namur, on the north end of the Kwajalein Atoll, was equipped to watch Russian ICBM flights over North Pacific Ocean areas.

Prior to 1963, Kwajalein was under the command of the Navy. The Army and Air Force also had activities on the islands. In 1963, the Army was selected as the new commanding agency. In July 1964, the U.S. Navy formally transferred command of Kwajalein Pacific Missile Range Facility, which later became known as Kwajalein Test Site (KTS), to the Army. The project office was located at Redstone Arsenal, AL.⁴²⁹

Long-term plans currently show funding at Kwajalein to decrease during the next fourteen years with the facility either being closed or becoming commercial around 2016.

B.5.2 Facilities

B.5.2.1 General

Due to its remote location, RTS combines all the assets of a Range with the facilities of a small city. Facilities include the following:

- Command & Control
- Air Field & Terminal
- Marina
- School
- Housing
- Radar
- Telemetry
- Optics
- Powerhouse
- Water Treatment

B.5.2.2 Launch

RTS launch facilities include a launch site on Meck Island, two 20K sounding rocket launchers at Roi-Namur Island (Figure B.5-3), and a 5K sounding rocket launcher at Kwajalein Island.

The Meck Island site has the larger launch facilities. It has supported the Homing Overlay Experiment (HOE), the Exo-atmospheric Reentry Interceptor Subsystem (ERIS)(Figure B.5-4), and the current Exo-atmospheric Kill Vehicle (EKV) tests providing critical development tests for the National Missile Defense (NMD) program⁴³⁰.

⁴²⁹ <http://www.angelfire.com/hi2/kwa/>

⁴³⁰ http://www.smhc.army.mil/kwaj/KMR_INTC.HTM



Figure B.5-3 Sounding Rocket Launch from Roi-Namur

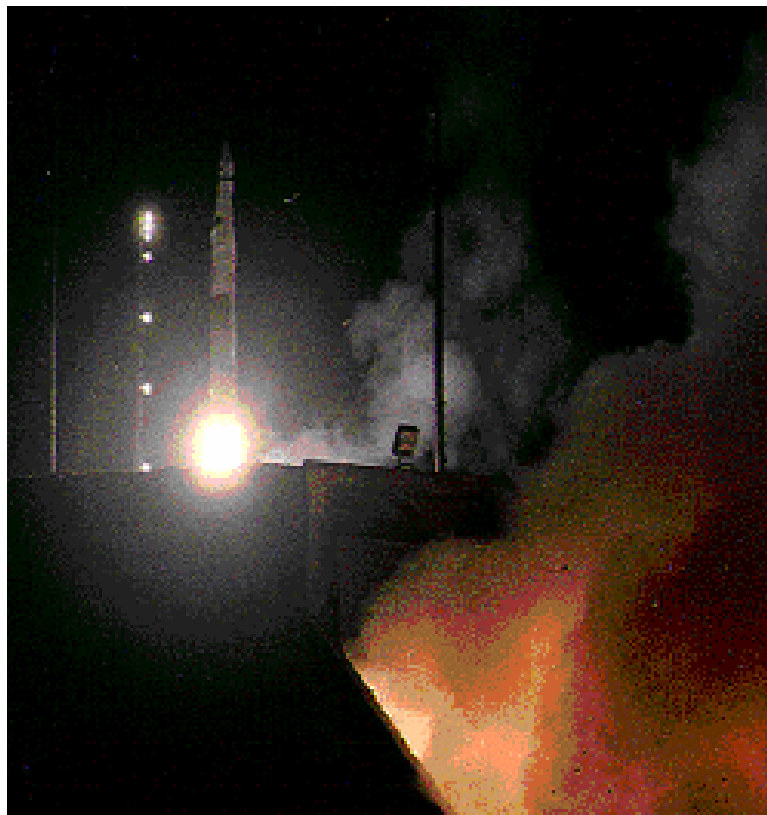


Figure B.5-4 ERIS Launch From Kwajalein

RTS also is involved in interceptor testing using alternative launch sites at Wake Island (Figure B.5-5) and other islands. These are shown in Figure B.5-6.

In addition to the RTS-supported facilities, RTS provides support for visiting tactical interceptor systems such as the PATRIOT system and the Theater High Altitude Area Defense (THAAD) system.



Figure B.5-5 Wake Island Launch

Range Safety support functions, in-flight vehicle monitoring, and interceptor targeting. A summary of the Telemetry antennas is given in Table B.5-1⁴³¹.

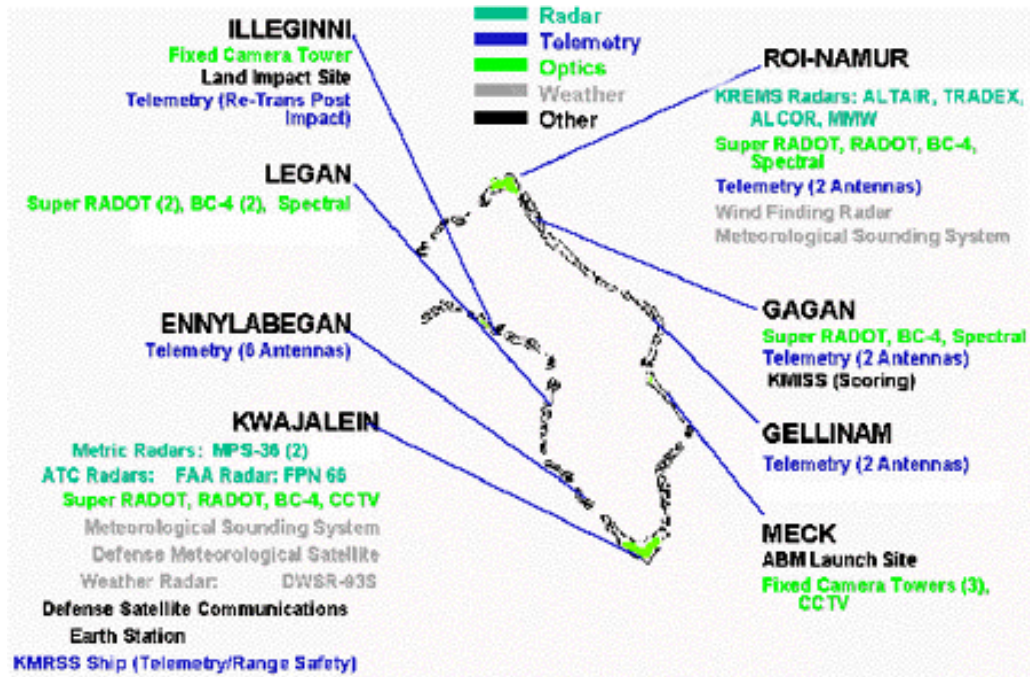


Figure B.5-7 RTS Instrumentation

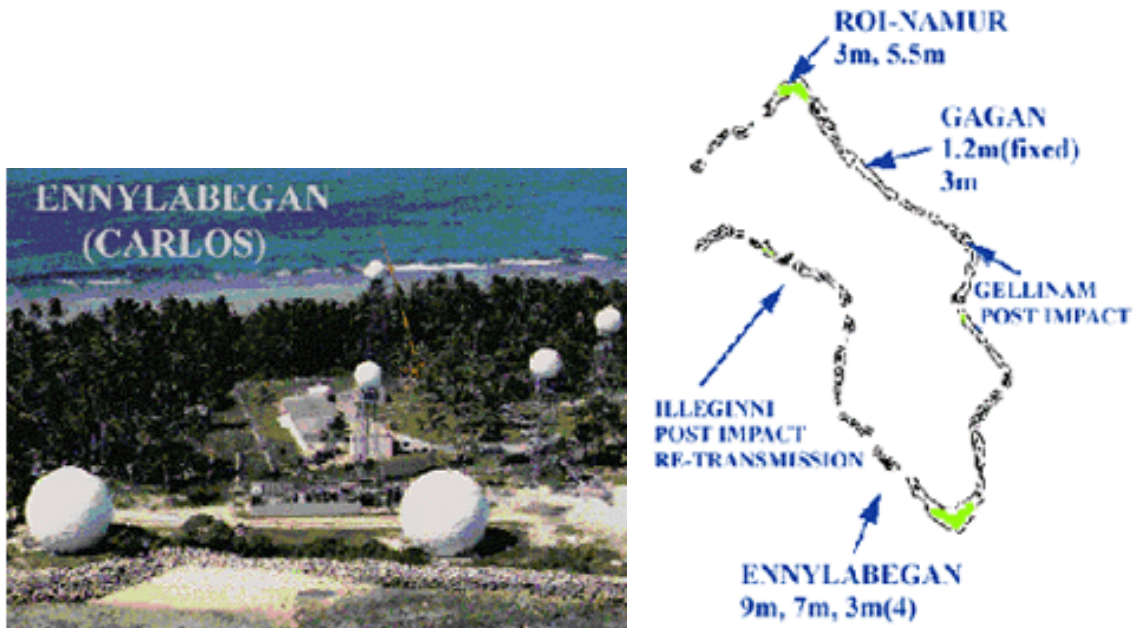


Figure B.5-8 RTS Telemetry Sites

⁴³¹ http://www.smdc.army.mil/KWAJ/KMR_TM.HTM

Table B.5-1 RTS Telemetry Antennas

Antenna Diameter	Gain*(dB) @ 2.25 GHz	Ts (K°)	G/T (M')	3 dB Beam width	Frequency (GHz)
Ennylabegan Nos. 1-4 (3 m)	34.6	400	9.0	3.0°	1.7-2.4
Ennylabegan No. 5 (7 m)	42.3	350	16.5	1.3°	1.7-2.4
Ennylabegan No. 6 (9 m)	43.6	350	18.0	1.2°	1.7-2.4
Roi-Namur 3-meter	34.6	400	9.0	3.0°	1.7-2.4
Roi-Namur 5.5-meter	39.8	350	15.0	1.76°	1.7-2.4
Gagan 3-meter	34.6	400	9.0	3.0°	1.7-2.4
Gagan 1.2-meter	19.5	500	-7.5	15.0°	2.2-2.3

Radar

RTS has a large assortment of radars. These include the following:

- ARPA Lincoln C-Band Observable Radar (ALCOR)⁴³² – Figure B.5-9
- ARPA Long-Range Tracking and Instrumentation Radar (ALTAIR)
- Tracking and Discrimination Experiment (TRADEX) – Figure B.5-10
- Millimeter Wave Radar (MMW) – Figure B.5-11
- MPS-36 C-band Multipurpose – Figure 3.5-12

⁴³² http://www.smdc.army.mil/KWAJ/ALC_SPEC.HTM



Figure B.5-9 ALCOR Radar



Figure B.5-10 TRADEX Radar

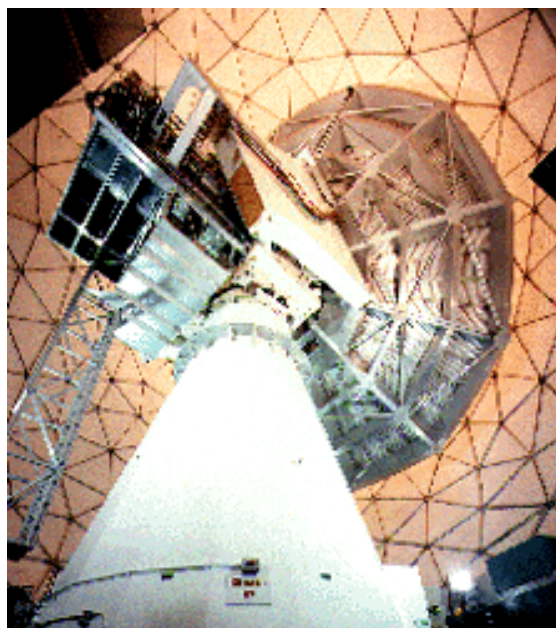


Figure B.5-11 **Millimeter Radar**



Figure B.5-12 **MPS-36 Radar**

Optics

RTS optic sensors include the following:

- Recording Automation Digital Optical Tracker (RADOT) – Figure B.5-13
- Super RADOT



Figure B.5-13 **RTS Optical Tracking Camera**

Other Sensors

RTS frequently hosts a variety of mobile sensors. These include the following⁴³³:

- Airborne Surveillance Test bed (AST) – Figure B.5-14
- Cobra Eye⁴³⁴ – Figure B.5-15
- Cobra Judy⁴³⁵ – Figure B.5-16
- Halo⁴³⁶ - Figure B.5-17



Figure B.5-14 **Airborne Surveillance Test Bed**

⁴³³ http://www.smdc.army.mil/KWAJ/KMR_MBLs.HTM

⁴³⁴ <http://www.smdc.army.mil/KWAJ/cobraeye.html>

⁴³⁵ <http://www.smdc.army.mil/KWAJ/cobrajud.html>

⁴³⁶ <http://www.smdc.army.mil/KWAJ/halo.html>



Figure B.5-15 Cobra Eye



Figure B.5-16 USNS Observation Island (Cobra Judy)



Figure B.5-17 Halo

B.6 KODIAK

B.6.1 Background

The Kodiak Launch Complex (KLC) is located about 250 miles south of Anchorage, AK on Kodiak Island (Figure B.6-1). It was built in 1998 by the Alaska Aerospace Development Corporation (AADC). The AADC is a public corporation created in 1991 to develop aerospace-related economic, technical, and educational opportunities for the State of Alaska. KLC was designed by BRPH Architects-Engineers, Inc. of Melbourne, FL. The Kodiak Launch Complex is the only commercial launch range in the United States not co-located with a federal facility. Kodiak's greatest advantage is its wide-open launch corridor and unobstructed down-range flight path.⁴³⁷



Figure B.6-1 Kodiak Launch Complex

B.6.2 Facilities

B.6.2.1 General

Primary facilities at KLC include the following:

- Launch Control & Management Center (Figure B.6-2)
- Payload Processing Facility (Figure B.6-3)
- Integration & Processing Facility (Figure B.6-4)
- Space Craft Assembly Transfer (Figure B.6-4)
- Launch Pad (Figures B.6-5, B.6-6)

⁴³⁷ <http://www.akaerospace.com/frames1.html>



Figure B.6-2 Launch Control & Management Center



Figure B.6-3 Payload Processing Facility



Figure B.6-4 **Spacecraft Assemblies Transfer**



Figure B.6-5 **Launch Pad 1**



Figure B.6-6 Launch Pad 1 With Enclosure

B.6.2.2 Launch

Kodiak was designed to support both solid and liquid fueled rockets. The first launch was an interceptor rocket on October 5, 1998 as a part of the USAF Atmospheric Interceptor Technology. Launch number two was about a year later, on September 15, 1999 for a similar mission. On September 30, 2001, a Kodiak Star launch vehicle, Athena I rocket (Figure B.6-7), was launched with three Amateur Radio payloads⁴³⁸.

⁴³⁸ <http://www.arrl.org/news/stories/2001/10/01/2/?nc=1>



Figure B.6-7 Kodiak Star Launch Vehicle (Athena I)

B.6.3 Instrumentation

The KLC does not presently contain a significant amount of tracking and monitoring sensors. Portable telemetry equipment is usually provided by Wallops⁴³⁹. Equipment is set up on Kodiak Island and on the mainland at Cordova, AK. A radar is also located at Cordova. Remote area safety aircraft are used to monitor the missile flight⁴⁴⁰.

⁴³⁹ <http://www.spacedaily.com/news/kodiak-01a.html>

⁴⁴⁰ http://www.huntsville.edaw.com/files/northpacific/nptp_ground_flight_safety_board.pdf

B.7 WHITE SANDS MISSILE RANGE

B.7.1 Background

B.7.1.1 Location

White Sands Missile Range (WSMR) is located in south-central New Mexico, near the town of Las Cruces (Figure B.7-1 and Figure B.7-2⁴⁴¹) and just North of El Paso, Texas. It gets its name from the world's largest gypsum dune field⁴⁴². For thousands of years, the prevailing westerly winds have deposited gypsum powder, eroded from the nearby San Andres Mountains, washed down by rainwater, and deposited in the seasonal Lake Lucero; creating a huge area of white dunes covering 275 square miles. About half of the sands are within the boundaries of the White Sands National Monument, which is located in the southern portion of WSMR.

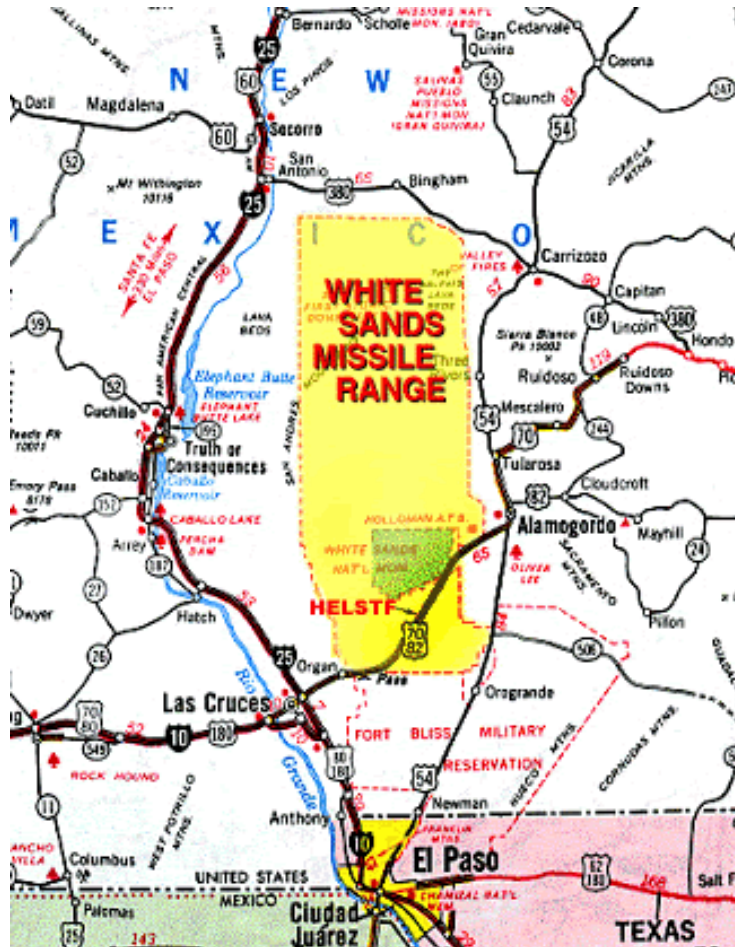


Figure B.7-1 White Sands Missile Range

⁴⁴¹ <http://wstc.wsmr.army.mil/visit/Tour/index.html>

⁴⁴² <http://www.nps.gov/whsa/>

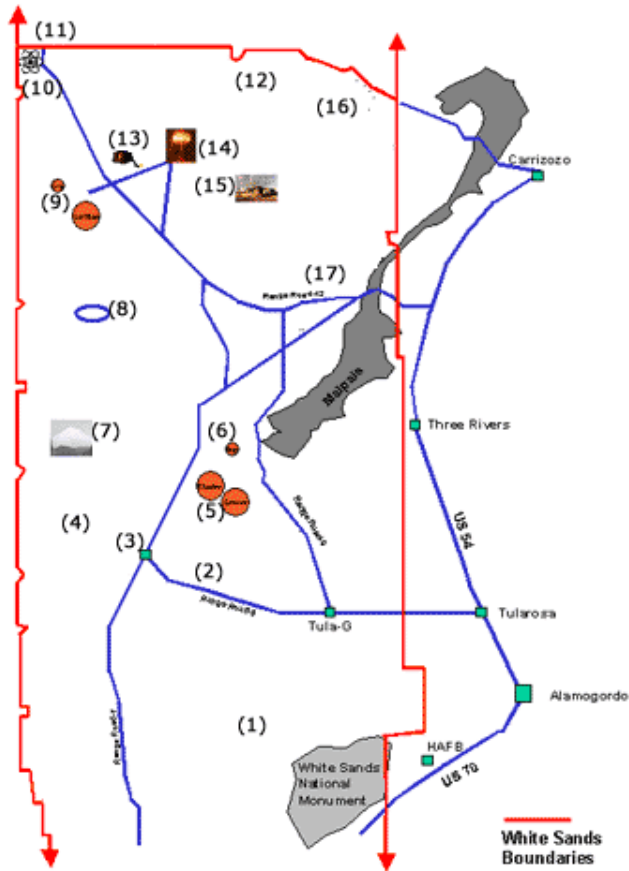


Figure B.7-2 White Sands Missile Range Sites

- | | | | |
|---|-----------------------------|----|---|
| 1 | NRTF | 10 | Large Blast Thermal Simulator |
| 2 | Toby Town Target Area | 11 | Stallion Range Center |
| 3 | Rhodes Canyon | 12 | N. Oscura Peak |
| 4 | RAMS | 13 | Permanent High Explosive Test Site |
| 5 | Rhodes & Denver Impact Area | 14 | Trinity Site |
| 6 | PUP Warhead | 15 | McDonald House (base for Manhattan project) |
| 7 | Salinas Peak | 16 | Red Rio Impact Site |
| 8 | Zumwalt Track | 17 | Oscura Impact Range |
| 9 | Stallion (PII) | | |

The Trinity Site, where the first atomic bomb was detonated in July 1945, is located on the northern portion of WSMR. This is shown as item #14 in Figure B.7-2. Tourists may visit the site only on 2 days each year, on the first Saturdays of April and October, when guided tours are provided.

Just to the east of White Sands National Monument is Holloman Air Force Base; a few miles north is the space shuttle landing sites; to the south is Ft. Bliss⁴⁴³.

White Sands Missile Range is the largest overland test range in America. It is a part of the US Army's Development Test Command. It includes support facilities for the Army, Navy, Air Force and NASA.

B.7.1.2 History

White Sands is the oldest missile range in the U.S. On February 8, 1945, the War Department directed that land be obtained to establish a land range where missiles could be test fired and recovered for analysis. The Tularosa Basin of southern New Mexico was selected. Some of the area was ranch land, but a large portion was already owned by the War Department and was comprised of Fort Bliss Anti-aircraft Firing Range, Dona Ana Target Range, Castner Target Range and Alamogordo Army Air Field's Bombing range. This area eventually became White Sands Proving Grounds and, in April of 1958, it became White Sands Missile Range.

The first launch from White Sands was a Tiny Tim Booster on September 26, 1945. Launch complex 33, the site of this first launch, is now a National Historical Landmark (Figure B.7-3). It was later used for V-2 launches, along with the Nike Ajax, Nike Hercules, Viking, Corporal, Redstone, Lance, Multiple Launch Rocket System, and Army TACMS. The complex is still used today for initial test firings of new missiles under development⁴⁴⁴.

Prior to the establishment of White Sands Missile Range, Dr. Robert Goddard performed some of his pioneering rocket development near Roswell, New Mexico in the 1930s.

In 1945, after the US Army seized V-2 components and 115 German rocket specialists, the men and equipment, led by Wernher von Braun, were relocated to Ft. Bliss, Texas and then to White Sands, New Mexico. Starting in April of 1946, and continuing to 1952, sixty-seven V-2 rockets were test fired from White Sands.

The V-2 (Figure B.7-4) could deliver a 2,000-pound warhead at supersonic speeds to target areas 150 miles away. The Germans fired about 3,600 V-2s at targets in England and on the continent during WWII. The architect of the rocket was Dr. Wernher von Braun, who based much of his design on the pioneering work done by Dr. Robert Goddard.

⁴⁴³ http://www.americansouthwest.net/new_mexico/white_sands/national_monument.html

⁴⁴⁴ <http://www.wsmr-history.org/History.htm>



Figure B.7-3 Launch Complex 33



Figure B.7-4 V-2 Rocket

Early V-2 testing gave the United States valuable experience in assembling, pre-flight testing, handling, fueling, launching, and tracking large missiles. The scientific experiments conducted aboard the V-2 provided new information about the upper atmosphere, our first photographic look back at the earth from space, the first experience with a large two-stage rocket, and carried the first biological experiments into space⁴⁴⁵. The V-2 led to the Redstone and Jupiter missiles, which led to the Saturn series which culminated in the capability to send men to the moon.

On 5/29/1947, a V-2 went the wrong way and landed in a cemetery south of Juarez, Mexico. No one was injured, but this event led to the decision to find another launch location for large rockets. Candidate locations included California, Alaska, and Florida. The California site was a prime candidate until Mexico refused to allow missile over-flights. This led to the eventual selection of Cape Canaveral, FL.

B.7.2 Facilities

B.7.2.1 General

Some major facilities at WSMR are identified in the following paragraphs:

White Sands Test Center

The White Sands Test Center is responsible for planning and conducting tests at WSMR. It is made up of the following six major directorates.

National Range Operations Directorate - The NRO manages range instrumentation, range operations, data collection and reduction, and flight safety of all missiles, rockets, munitions, lasers, etc. The Flight Safety Officer is a part of this directorate.

Materiel Test Directorate - The MTD tests military hardware systems including air defense systems, main battle tank and artillery ordnance.

Directorate for Applied Technology, Test & Simulation - This directorate is a recognized center of expertise for nuclear effects testing and evaluation. It also evaluates electronic warfare, electro-optical, electromagnetic, and lightning effects.

Technology Development Directorate - This directorate is responsible for the development and acquisition of technology, range instrumentation, equipment and facilities for White Sands. Some of the equipment they have acquired is listed in the other paragraphs in this section.

⁴⁴⁵ <http://www.wsmr-history.org/V-2.htm>

Information Operations Directorate - This directorate provides real-time test support in engineering, planning, modifications, installation, operations and maintenance for telecommunication and automation at White Sands.

Environment and Safety Directorate - The Environment and Safety Directorate (ES) provides support and services to range customers through its operating divisions.

Tenant Organizations⁴⁴⁶

Desert Navy – The Navy has been part of the test community at White Sands since June 14, 1946, when Naval activity was established to participate in research and testing of captured German V-2 rockets. Today, the mission of the Naval Air Warfare Center Weapons Division-White Sands includes land-based test of Naval weapon systems (missiles and gun munitions) and launch operations for sub orbital space systems and research rockets. The Navy facilities include the U.S.S. Desert Ship. The Desert Ship serves as a primary live fire test bed for surface-to-air weapons including Standard Missile and Evolved Sea Sparrow Missile.

U.S. Air Force – The Air Force Development Test Center at Eglin AFB operates a fleet of high performance aircraft in support of weapons testing.

White Sands Test Facility (NASA) – NASA started using WSMR in 1962 to test engines in the Apollo command Service Module and the Lunar Module. Recent activities include continued space shuttle support and testing of the Delta Clipper (Figure B.7-5). NASA facilities also include the following:

- **WSSH** - White Sands Space Harbor
- **TDRS** - Tracking and Data Relay Satellite

WSSH – The White Sands Space Harbor is the primary training area for space shuttle pilots flying practice approaches and landings in the shuttle-training aircraft, a modified Gulfstream II. The north-south runway (Figure B.7-6) is configured to simulate the runway at Kennedy Space Center, while the east-west runway simulates the lakebed runway at Edwards Air Force Base. A third, shorter runway simulates the transatlantic abort-landing site at Ben Guerir, Morocco, and is used to simulate training at Moron, Spain and Banjul, The Gambia. WSSH is an alternate landing site for the shuttle. STS-3 landed here in 1982 (Figure B.7-7). Its long, forgiving, hard surface is ideal for emergency landings.

⁴⁴⁶ <http://www.wsmr.army.mil/paopage/pages/orgind.htm>



Figure B.7-5 Delta Clipper (1993)



Figure B.7-6 Runway 17



Figure B.7-7 Shuttle Columbia Landing 1982



Figure B.7-8 TDRS Ground Station

TDRS - The NASA Tracking and Data Relay Satellite system ground station (Figure B.7-8) is adjacent to the NASA test facilities. The TDRSS complex contains three 60-foot diameter high-gain microwave antennas to send and receive commands and data to and from the geosynchronous-orbiting array of TDR Satellites. The satellites receive and relay data from a multitude of low-Earth-orbit (LEO) satellites, the Space Shuttle, and the International Space Station. TDRSS replaced an entire network of expensive, aging tracking stations and ships located throughout the world.

U.S. Army TRADOC Analysis Center - Conducts operations research on Army organizations and systems.

Army Research Laboratory - The Army's primary source of fundamental and applied research

Center for Countermeasures – This is DOD's focal point for guided weapons countermeasures/counter-countermeasures analysis and testing.

High Energy Laser System - Operates the nation's most powerful laser in support of DOD laser research, development, test and evaluation.

Ground-Based Electro-Optical Deep Space Surveillance - This site supports Cheyenne Mountain through its tracking of deep space objects.

Range Commanders' Council Secretariat – Provides administrative services to the Range Commanders' Council.

U.S. Army Electronic Proving Ground, Ft. Huachuca - Provides time, space, position information (TSPI) and target signals and provides large-scale antenna test facilities.

B.7.2.2 Launch

White Sands Test Center operates over fifty unique launch facilities supporting surface-to-air and surface-to-ground weapon testing.⁴⁴⁷ The major launch facilities are described in the following paragraphs:

LC-33 - Launch Complex 33 was the first launch site constructed on the Range. This is the site of the V-2 rocket testing which began in 1945. It is designated as a National

⁴⁴⁷ http://wstc.wsmr.army.mil/capabilities/lab_fac/Launchfacilities.html

Historical Landmark. The complex is still used today for initial firings of many new missiles under development.

LC-34 - Launch Complex 34 was established as the land based test site for the Navy's Rolling Airframe Missile (RAM) program. This is a semi-hardened site used to flight test RAM against subscale and subsonic targets. The site is used to test various configurations of RAM missiles, weapon systems, support systems, and launchers.

LC-35 - Launch Complex 35 West - Launch Complex 35 West (LC-35W), known as the Desert Ship LLS-1, is primarily used for live fire testing the Navy's STANDARD Missile (SM). The Navy is currently testing the Standard Missile and Evolved Seasparrow Missile (ESSM) at this site. The Desert Ship functionally duplicates the fire control requirements of a surface ship with dedicated telemetry, target monitoring, and data extraction and reduction systems. A MK-39 5-inch/54 Gun Mount is also located here.

LC-35 East - Launch Complex 35 East is a Research Rocket facility that includes a blockhouse, launch control equipment and a payload assembly building. NASA currently uses this facility for payload buildup and uplink control of rocket payloads.

LC-36 - Launch Complex 36 launches sub-orbital rockets. It includes a blockhouse, launch control equipment, & launchers, some with environmental shelters. Launchers are:

- 37-foot rail with 8,000 lb capacity
- 48-foot rail with 25,000 lb capacity
- 160-foot rail (tower) with 8,000 lb capacity
- 48-inch diameter stool with 50,000 lb capacity
- 30-foot rail with 15,000 lb capacity. This mobile launcher can support off-range operations

LC-37 - Launch Complex 37 is the Advanced Gun Munitions Test Site and includes a concrete structure housing various advanced gun systems, a permanent bunker and a concrete pad. LC-37 had been designated as the facility to test the new Theater Missile Defense interceptors.

LC-38 - Launch Complex 38 has been used for all Patriot air defense missiles testing, beginning in the early 1970s, when it was known as SAM-D.

Sulf Site Launch Facility - This complex is located at the northwest end of the Range and is equipped with a blockhouse and ordnance assembly building, three active launchers, and a 65-foot environmental shelter. This complex is used to launch targets to support missile intercept testing and to launch technology demonstrations or unique science and engineering payloads into sub-orbital trajectories.

WC-50 - West Center 50 is located in the central portion of the Range near Rhodes Canyon. This facility includes a hardened blockhouse and accommodates testing of short-range systems without a Flight Termination System.

B.7.2.3 Major Test

White Sands contains many other major test facilities:

300K Dynamic Test Facility – This facility is used for static firing/dynamic burst testing of rocket motors 40" in diameter.

Aerial Cable Range – The Aerial Cable Range (Figure B.7-9) is located in the north central area of the range. The three-mile long cable is suspended between two mountain peaks and is the longest unsupported cable span in the world. The cable, which can support up to 20,000 lbs, serves as a path for captive vehicles. The Aerial Cable Facility can be used to provide cost-effective testing on bombs, sensors, missiles, sub-munitions, prototype aircraft electronics, target and clutter characterizations, and electronic countermeasures and warning devices. Vehicles can be accelerated by gravity or rocket at controlled speeds up to 150 knots for gravity accelerated items and up to 250 knots for rocket assisted items. Altitudes can be varied from 100 to 1000 ft. above ground level.⁴⁴⁸

⁴⁴⁸ http://wstc.wsmr.army.mil/capabilities/lab_fac/aerialcabledrange.html



Figure B.7-9 Aerial Cable Range

NASA Test Facilities

- Six test stands provide vacuum test capability (Figure B.7-10)
- Three test stands provide ambient testing (Figure (B.7-11))



Figure B.7-10 **Typical Altitude Test Stand**



Figure B.7-11 **Ambient Test Stand**

NRTF – National RCS Test Facility is used for radar target signatures (Figure B.7-12)



Figure B.7-12 National RCS Test Facility (NRTF)

LB/TS - The Large Blast Thermal Simulator (Figure B.7-13) is designed to simulate the thermal pulse and air blast wave from a nuclear detonation. Customers with nuclear survivability requirements can test full-scale vehicles and systems year-round, inside or outside the tunnel (Figure 3.7-14). The tunnel is a 170-meter long, 20-meter diameter concrete shock-tube, which uses heated dry nitrogen to produce a blast wave and a Thermal Radiation Source (TRS) to produce a simulated thermal pulse.

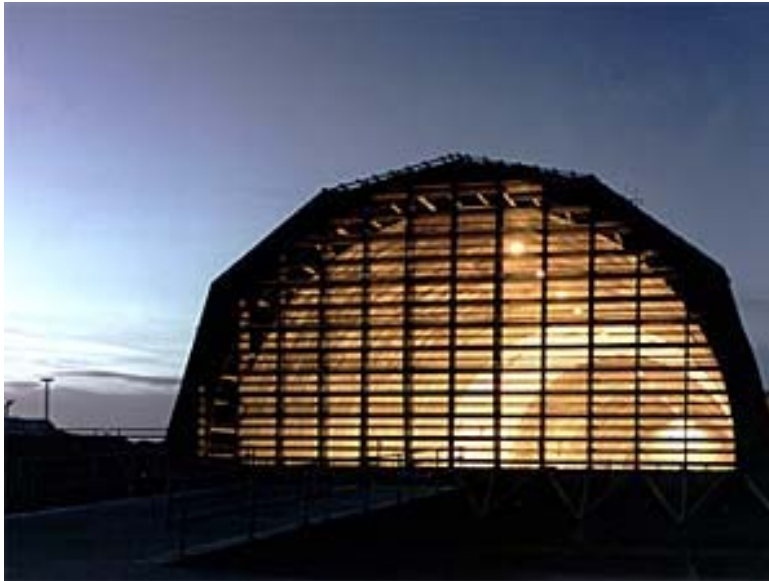


Figure B.7-13 Large Blast Thermal Simulator

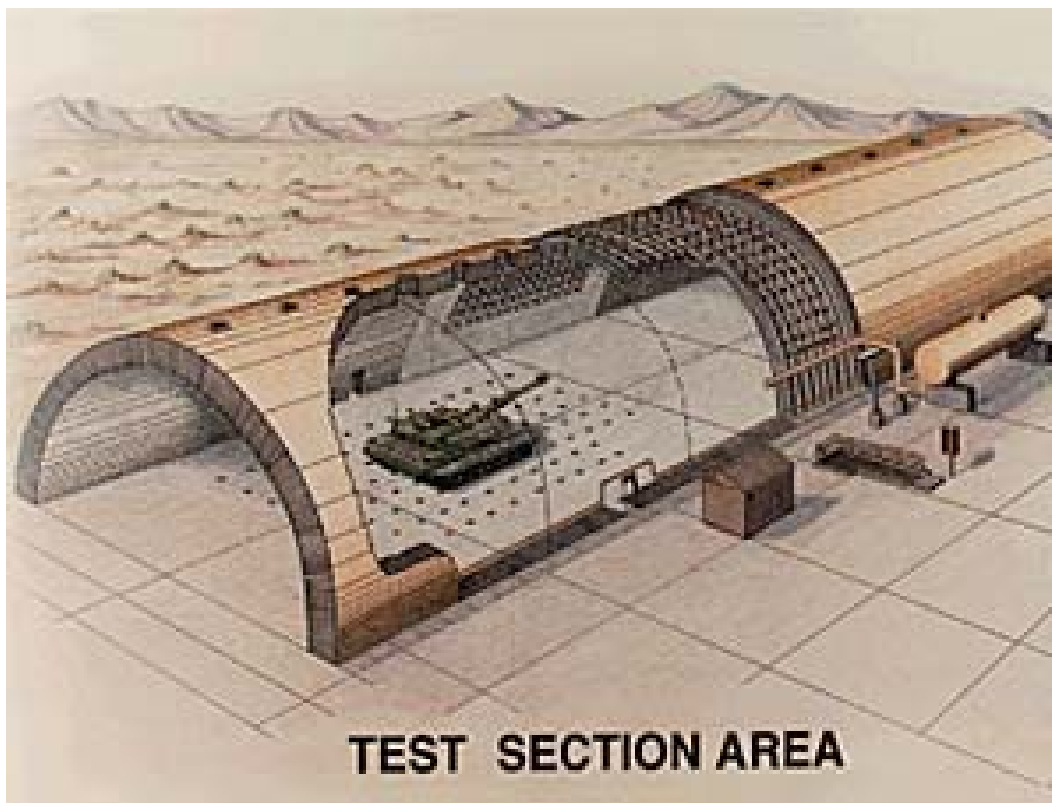


Figure B.7-14 **LB/TS Tunnel**

RAMS – The Radar Cross Section Advanced Measurement System (Figure B.7-15) is used to measure monostatic radar cross section of objects up to 70 feet in diameter.



Figure B.7-15 **RCS Advanced Measurement System**

NOP – The North Oscura Peak site (Figure B.7-16) overlooks the valley 3000 feet below. It is used by the Air Force for Airborne Laser and other programs.



Figure B.7-16 **North Oscura Peak**

HELSTF⁴⁴⁹ – The High Energy Laser Systems Test Facility (Figure B.7-17) was started in White Sands in 1970 to support development of lasers as weapon systems. The Test Facility represents an approximately \$800 million investment in High Energy Laser research. It includes the following lasers:

- **MIRACL** – Mid-Infrared Advanced Chemical Laser
- **THEL** - Tactical High Energy Laser

⁴⁴⁹ <http://helstf-www.wsmr.army.mil/index.htm>



Figure B.7-17 HELSTF

MIRACL⁴⁵⁰ – The Mid-Infrared Advanced Chemical Laser (Figure B.7-18) is the most powerful chemical laser in the Western Hemisphere. MIRACL has proved that chemical laser technology can be scaled to multi-megawatt power levels.

THEL – The Tactical High Energy Laser (Figure B.7-19) is the world's first laser weapon system developed for deployment. Testing began in 1999.



⁴⁵⁰ <http://helstf-www.wsmr.army.mil/miracl.htm>

Figure B.7-18 MIRACL**Figure B.7-19 THEL Beam Director**

High Speed Sled⁴⁵¹ – A 10-mile long High Speed Test Track is located at adjacent Holloman AFB on the border with WSMR. It offers precise effective low, medium, and high dynamic operating environment for testing, evaluating, and validating GPS-based guidance and control systems, inertial navigation systems, and truth reference systems. The High Speed Test Track is a rocket test and aerospace test facility which provides an efficient and safe means of testing customer test items, while minimizing risks and reducing cost for a wide variety of test hardware in a near operational environment. Speeds approaching 10,000 feet per second (Mach 9) are possible. This facility is discussed more in Section B.14.

B.7.2.4 Communications

The WSMR Communication Network provides digital electronics transport of voice, data, telemetry, video, and other information within WSMR. It also interfaces with commercial carriers for off-range and inter-range services. The network is comprised primarily of single mode fiber (high data rate fiber optics cable.) It has terminal electronic equipment that provides multiple layers of redundancy in the event of equipment failure. Two digital microwave systems at Salinas Peak are integrated with the fiber optics system. The network is transitioning to full Synchronous Optical Network

⁴⁵¹ <http://wstc.wsmr.army.mil/capabilities/testbed/higspesletra.html>

(SONET) capability. Interface to the electronics equipment is done by the North American hierarchy formats (DS-0, DS-1, and DS-3). Conventional encryption and other driver devices with standard data rates can be inserted at any interface point. Centralized remote monitoring, diagnostics, and network control permit operation and maintenance with minimum personnel and physical plant resources. This reduces overhead costs to Range customers. A real-time data system transmits data from instrumentation to the Real-Time Operations Control System in the Range Control Center. The standard channel capability is 9,600 bits/sec using data modulator/demodulator units on standard voice frequency cable pairs, and fiber optics or microwave channels. Higher rate and non-standard information, such as telemetry data, are transmitted via wide-band fiber optics or microwave systems.

Real-Time Telecommunications Support - WSMR provides real-time direct test support and telecommunications services including command and control flight termination of unmanned test vehicles, range voice and data transmission systems, UHF and VHF radios, local and wide area networks, single and multi-channel intercoms, telephones, frequency and spectrum management, and portable technical control facilities using microwaves. Specially configured circuitry and extensive state-of-the-art copper and fiber optic cable and digital microwave transport systems are used as the primary transport and distribution systems to meet the needs of complex test support entities throughout the Range.

Frequency Surveillance - WSMR performs frequency surveillance, evaluation and radiation analysis, and controls the use of all radio frequencies. Frequency scheduling is performed on a daily basis. All frequencies used in connection with Range missions are monitored. Transmitter, receiver, and antenna frequency spectrum usage and electromagnetic propagation are analyzed to develop interference tolerances, interference reduction and prevention programs, and to identify radiation hazard distances from emitters. Frequency surveillance (both fixed and mobile) is provided within a 150-mile radius of WSMR Headquarters and in portions of Colorado and Utah.

Mobile Radio Systems - Mobile radio systems are used extensively at WSMR for coordinating the efforts of field personnel, optimizing the use of vehicles and mobile instrumentation, and for Range customer communications. There are mobile units, base stations, repeaters, and portable radios. Many radio nets are repeater operated; with one or two repeaters, several base stations, and many mobile units (vehicle mounted and hand held). To cover a large area, the repeaters are usually located on mountain peaks. Some of the radio nets can operate in either the clear mode or the secure (encrypted) mode.

Telecommunications - WSMR provides Transmission Engineering and Universal Documentation System (UDS) requirements support to Range customers. The Transmission Engineering Support Office augments the existing communications network, as required, to ensure adequate facilities exist to provide the services identified to the Requirements Office. This includes copper and fiber optic cabling, Lightwave transmission systems (i.e., SONET, etc.), Microwave systems, Carrier systems, telephone systems, special one-of-a-kind circuits, etc.

VHF and UHF Communications - VHF and UHF ground-to-air communication radios are located at Salinas Peak, Clark Site, King-I, C-Station, Stallion, and North Oscura Peak. This radio system uses the air traffic control standard aircraft radios. This capability provides WSMR with voice communications to all aircraft involved in range activities

Transportable Systems - Transportable communications systems are used to support off-range, interim, and emergency requirements. The systems consist of various 23 GHz transportable microwave radios providing remote-location digital communication links for telephone, data, and voice circuits. These systems are assembled on a program requirement case-by-case basis and consist of transportable, 1000-watt radio command guidance and control units capable of transmitting the 20 standard Inter-Range Instrumentation Group (IRIG) tones.

B.7.3 Instrumentation

Significant Range instrumentation includes the following:

- Radar
- Telemetry
- Optics
- Timing
- GPS
- Weather
- Portable Range

Radar

Instrumentation radar systems consists of the following⁴⁵²:

- (11) AN/FPS-16 C-Band SOTR (Single Object Tracking Radar)
- (1) AN/MPS-25 C-Band SOTR
- (4) AN/MPS-36 C-Band SOTR
- (2) AN/MPS-39 MOTR (Multiple Object Tracking Radar)
- (1) MIDI (Miss Distance Measurement Instrument)
- (1) Weibel Monopulse Doppler Radar
- (3) ASR-9 Airport Surveillance Radars
- (1) GPN-20 Air Surveillance Radar
- (1) APARS Advanced Phased Array Radar System
- (1) RHVTS

⁴⁵² http://wstc.wsmr.army.mil/capabilities/range_inst/radar/instrum.html

Except for four of the AN/FPS-16's, all radars are transportable. The instrumentation radars provide Time Space Position Information (TSPI) on objects under test, as well as target motion analysis and target signature information.

The highly accurate instrumentation radars provide both cooperative (transponder) and non-cooperative (echo) target tracking and are located at optimum sites for Range customer support. The radars are connected by the Range communications system to the Real Time Data Processing System (RTDPS) at the Range Control Center. Track data from the radars flows into the RTDPS; while processed cueing data from the radars and other tracking sources is transmitted from the RTDPS to the radars. The radars also provide acquisition data directly to each other, optics instruments, and telemetry trackers through the Radar Acquisition Data System (RADS).

AN/MPS-36 - These C-Band Single Object Tracking radars are being modernized through replacement of the antenna, antenna feed system, and replacement of the two-channel receiver with a three-channel unit.

MOTR – A Multiple Object Tracking Radar can track up to 10 objects at one time. The two WSMR MOTRs (Figure B.7-20 & B.7-21) have been converted to track four times as many objects. They are the workhorse instrumentation radars at White Sands. Each can track up to forty objects simultaneously over a 60-degree field of view without loss of tracking accuracy. The phased array antenna is located on a standard elevation over azimuth servo-controlled mount, so full hemispheric coverage is possible. The MOTR has a variety of waveforms, ranging from .25 microseconds to 50 microseconds; making it an extremely sensitive instrumentation radar. Targets as small as six inches in diameter can be accurately tracked at distances exceeding 200,000 yards. The MOTR is a fully coherent radar (e.g., the phase relationship of the transmitted pulse is maintained). This allows accurate Doppler and Target Motion Resolution measurements using post-test processing techniques. Semi-permanent MOTR sites have been established at the south end of the range at Wise Site, and in the mid-range area at Rita Site.

MIDI - The X-Band Miss Distance Measurement Instrument (Figure B.7-22) provides near real-time vector miss distance data, including both distance and direction to the point of nearest approach of missiles and projectiles fired at an aerial target. Auxiliary equipment includes a microprocessor-interfaced XY plotter with a floppy disc, a gunfire interface, muzzle velocity radar, and a Radar Acquisition Data System console for data interface. The gunfire interface detects firing pulses and counts rounds. The muzzle velocity radar measures the muzzle velocity of rounds. The raw data is processed on-site to derive scoring results. Quick look data is available in about six minutes. The system is transportable.



Figure B.7-20 MOTR (trailer mounted)



Figure B.7-21 MOTR (fixed site)



Figure B.7-22 Miss Distance Indicating Radar

Weibel Radar - The Weibel monopulse Doppler radar (Figure B.7-23) is a 240-Watt, active, real-time Continuous Wave (CW) tracking system that measures radial velocity and azimuth and elevation to the target. The angle measurement is based on monopulse angle discrimination techniques. High-speed digital-signal processing calculates the direction to the target. Since the radar is normally located close to the launcher, track acquisition is very quick. Post-test processing provides time, range (integrated velocity), azimuth, elevation, signal strength, position, velocity, acceleration, and other parameters for targets within the beam. The Weibel radar can be used to track a variety of objects including small caliber ammunition, rockets, and missiles.



Figure B.7-23 Transportable Weibel Antenna System

ASR-9⁴⁵³ – The Airspace Surveillance Radar system consists of three ASR-9 radars. Range control and range safety officers use the ASR-9s to ensure aircraft safety and to detect unauthorized flights into the WSMR restricted airspace. The airspace restriction over the main range extends from the surface to an unlimited altitude. The ASR-9 radar collects range and azimuth data from an IFF source on the aircraft through a secondary radar. Data is transmitted through the Range Communications System to the Airspace Display and Control Center located in the Range Control Center. The system is active 24 hours/day, 7 days/week and is manned for all scheduled hot operations.

GPN-20 – A single GPN-20 radar is used for air surveillance.

APARS – An Advanced Phased Array Radar System is being developed⁴⁵⁴. This new transportable instrumentation radar system will have the capability to track 120 targets in a 60-degree field of view. The system will be a wide band, active element Phased Array Radar System with three antenna configurations. The three antenna sizes will be 8, 12, and 18 feet. This radar system will look like two 8-foot systems, two 12-foot systems, and one 18-foot system.

RHVTS⁴⁵⁵ – The Ruggedized High Volume Tracking System (RHVTS) project will develop a compact ruggedized system for the collection of Time, Space, and Position Information (TSPI) from large numbers of live participants engaged in military test. The system is to provide a cost effective Geographic Information System (GIS) -based solution for the collection of TSPI data from a variety of platforms including ground vehicles, manpacks, and low dynamic aircraft. The system design will support the concurrent tracking of 200 participants and be upgradeable to at least 1000. The GIS will provide the capability to graphically represent range status and resources required to conduct test operations, support the resourcing of personnel and equipment, environmental conditions, and the general range status. Primary source of input is expected to be RHVTS participants, but data from other sources such as radar, telemetry, RAJPO GPS etc., can also be input.

Telemetry

The WSMR Telemetry instrumentation complex consists of fixed and mobile systems dispersed throughout the 40 mi. X 100 mi. missile range (Figure B.7-24) and in certain off-range locations (extensions) selected for optimum mission support. All Telemetry data from the field is transmitted to the Telemetry Data Center in the Cox Range Control Center via telemetry microwave relays, fiber optics, and by commercial means from off-range areas.

⁴⁵³ http://wstc.wsmr.army.mil/capabilities/range_supp/comm/comm-vhf.html

⁴⁵⁴ http://wstc.wsmr.army.mil/technology/range_instrument/radar.html

⁴⁵⁵ http://wstc.wsmr.army.mil/technology/range_instrument/radar/RuggHigh.html

Fixed telemetry sites are fully equipped stations to provide data acquisition, receiving and recording, and relaying. The telemetry system can receive, record, demultiplex, and format to IRIG 106 Telemetry standards⁴⁵⁶.

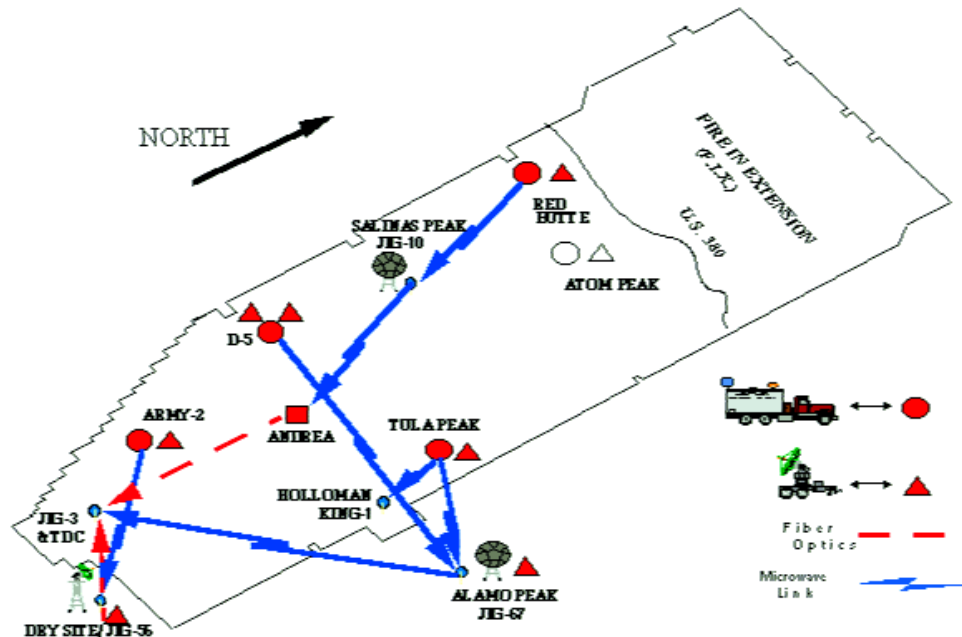


Figure B.7-24 Major Telemetry Sites

Major Telemetry assets include the following:

- TAS – Telemetry Acquisition Systems
- TTAS – Transportable Telemetry Acquisition Systems
- TTARS – Transportable Telemetry Acquisition and Relay System
- TMV – Telemetry Mobile Van
- MTS – Mobile Telemetry System
- TDC – Telemetry Data Center
- Telemetry Data Relay System

TAS – Telemetry Acquisition Systems are located at the following fixed sites:

- J-10 Salinas Peak (Figure B.7-25)
- J-67 Alamo Peak (Figure B.7-26)
- J-56 Dry Site (Figure B.7-27)

J-10 and J-67 are TAS-I sites with 24-ft tracking antennas. J-56 is a TAS-II site with a 15-ft tracking antenna. All sites support L-Band and S-Band.

⁴⁵⁶ <http://www.wsmr.army.mil/telemetry/publish/Index.html>



Figure B.7-25 J-10 - Salinas Peak Telemetry



Figure B.7-26 J-67 – Alamo Peak Telemetry



Figure B.7-27 **J-56 – Dry Site Telemetry**

TTAS – The Transportable Telemetry Acquisition Systems (Figure B.7-28) are used to supplement the fixed sites. The systems have 8-ft tracking antennas and support the L-Band and S-Bands.



Figure B.7-28 **Transportable Telemetry Acquisition System (TTAS)**

TTARS – A Transportable Telemetry Acquisition and Relay System (Figure B.7-29) is used for data relaying.

TMV – The Telemetry Mobile Van (Figure B.7-30) is used to for receiving and recording telemetry data.



Figure B.7-29 **Transportable Telemetry Acquisition & Relay System**



Figure B.7-30 **Telemetry Mobile Van**

MTS – The Mobile Telemetry System is a new state-of-the-art Mobile Telemetry System (Figure B.7-31) was recently added to the telemetry inventory. The MTS combines three separate functions (track, relay and record) that were previously performed by three separate mobile systems (TTAS, TTARS and TMV).



Figure B.7-31 Mobile Telemetry System

TDC – The Telemetry Data Center provides White Sands Missile Range with one of the premier telemetry data processing and display facilities within the Department of Defense. The TDC is capable of performing data distribution, demultiplexing, decommutation, tagging, merging, processing, data archival, and display of telemetry data in either preflight, real time or post flight mode. The TDC has implemented the necessary software to extract real-time telemetry data and present it in real time via PC based graphical displays and/or strip chart recorders. This visualization provides customers, such as Missile Flight Safety, with an intuitive grasp of the missile's spatial situation. All telemetry data is recorded for any required detailed data reduction. The data products of the TDC consists of the following: 1-inch 14-track analog tapes, serial or multiplexed Metrum helical scan tapes, Sony 8mm tapes, Digital Linear Tape, Compact Disks, Jazz Drive (1Gb/2Gb), Zip Disk (100Mb/250 Mb), Floppy Disk, and strip charts⁴⁵⁷.

Telemetry Data Relay - Digital microwave radio and fiber optic links are used to relay the telemetry data to the TDC. The Telemetry Acquisition and Relay System (TARS) consists of two Transportable Telemetry Acquisition and Relay Systems (TTARS) and four fixed relay and recording stations located at J-10, J-67, J-1 and J-56. Microwave links from J-10 and J-67 provide telemetry data to an Air Force telemetry ground station at Holloman Air Force Base. The TARS uses wide band digital microwave radio links to transport the telemetry carrier. The Digital Telemetry Acquisition and Relay System (DTARS) can carry high rate digital data from J-10 to J-56, from J-67 to the TDC, and from two mobile DTARS links to J-67. Each TTARS is equipped with digital radio. Each DTARS link can carry DS-3 (32 megabits/sec with multiplex) data rates.

⁴⁵⁷ http://wstc.wsmr.army.mil/capabilities/range_inst/telemsys/datacen.html

Optics

WSMR optic instrumentation includes the following:

- Cinetheodolites
- MATS - Multimode Automatic Tracking Systems
- LATS - Launch Area Theodolite Systems
- VTR - Versatile Tracking Mount
- DOAMS – Distant Object Attitude Measurement System
- Fixed Camera System
- CCTV - Closed Circuit Television
- Mobile Television Vans
- ALTS - Aided Laser Tracking System
- Video Relay Facility

Cinetheodolites – The cinetheodolite is an optical tracking instrument that provides precise angular measurements. The tracked object's image, azimuth and elevation angles are recorded on 35mm film or video.

MATS – The Multimode Automatic Tracking System (Figure B.7-32) is a mobile optical tracking system based on a version of the Contraves Kineto Tracking Mount (KTM).

LATS – The Launch Area Theodolite System (Figure B.7-33) is a mobile optical tracking telescope system similar to the MATS. The LATS are capable of tracking high dynamic targets at very close range to the target's trajectory. The LATS are ideally suited for tracking missile launches and high velocity impacts on ground-based targets. LATS are remotely controlled by the Remote Instrument Control System (RICS).



Figure B.7-32 Multimode Automatic Tracking



Figure B.7-33 Launch Area Theodolite System

VTR – The Versatile Tracking Mount is a mobile telescope used to obtain altitude, event, and missed distance data in situations where the slant range is large and large images are required.

DOAMS – The Distant Object Attitude Measurement System (Figure B.7-34) is a high performance, dual focal length (100 inch and 200 inch), large aperture, tracking telescope that simultaneously provides film recordings at both focal lengths. The DOAMS is used to obtain attitude, event, and miss distance data. The DOAMS is used for long ranges where high magnification and light gathering power are needed⁴⁵⁸.



Figure B.7-34 Distance Object Attitude Measurement System (DOAMS)

⁴⁵⁸ http://wstc.wsmr.army.mil/capabilities/range_inst/optics/distant.html

Fixed Camera System – The fixed camera system is comprised of a pre-oriented array of prism and pin-registered, high-speed cameras that photograph the object as it passes through their field of view. They are used at launch complexes, impact zones and the high-speed test track.

CCTV – The Closed Circuit Television is used for remote surveillance and instrumentation readouts under hazardous conditions.

Mobile Television Vans – These are used for temporary operations at remote locations. They are equipped with camera systems, microwave transmitters and receivers, and communications and switching equipment.

ALTS – The Aided Laser Tracking System is a laser tracking system used to provide Time, Space, and Position Information (TSPI) on missiles and aircraft.

Video Relay Facility – This facility is located in the Main Post area. It can receive and transmit video signals to the south range launch areas and to Alamo Peak for relay to Holloman AFB and Stallion Range Center

Timing⁴⁵⁹

The WSMR timing system generates and distributes IRIG standard time formats throughout the range. The master station is located in the south range. Its time standard is referenced to the Universal Time Standard maintained by the US Naval Observatory.

GPS

Global Positioning System instrumentation equipments are range assets that provide a variety of TSPI tracking methods for WSMR Flight Safety or customers.

Weather

WSMR provides a range of meteorological support including forecasts, observations, climatology studies, specialized products and consultation.

Portable Range

TRACS – Transportable Range Augmentation and Control System is under development. It will be a self-contained mobile system to support test mission planning/execution, real-time data collection and processing, mission control/flight safety and post mission data analysis.

⁴⁵⁹ WSMR Capabilities Handbook, 2001

B.8 POINT MUGU

B.8.1 Background

B.8.1.1 General

The Naval Air Weapons Station, Point Mugu, is a Navy test range located 65 miles northwest of Los Angeles (Figure B.8-1 and Figure B.8-2). It is part of the Naval Air Warfare Center Weapons Division (NAWCWD), the Navy's full-spectrum research, development, test evaluation, and in-service engineering center for weapons systems associated with air warfare (except for anti-submarine warfare systems), missiles and missile subsystems, aircraft weapons integration and assigned airborne electronic warfare systems. NAWCWPNS also maintains and operates the air, land, and sea Naval Western Test Range Complex (NWTRC). As a result of realignment actions taken in 2000, the base is now part of Naval Base Ventura County (NBVC), a consolidated organization that includes the former Construction Battalion Center, Port Hueneme and Naval Air Station, Point Mugu.



Figure B.8-1 Location of Pt. Mugu & Other Navy Test Facilities⁴⁶⁰

⁴⁶⁰ <http://www.nawcwpns.navy.mil/~pacrange/s1/HeloMap.htm>



Figure B.8-2 Point Mugu

Point Mugu's operations are frequently tied to joint operations at surrounding ranges⁴⁶¹:

- West: Vandenberg Air Force Base
- South: Navy's Southern California Offshore Range (SCORE)
 - These ranges frequently overlap and form one arena that can be expanded from Baja California north to Big Sur
- West coast activity links:
 - NAWCWD, China Lake, California
 - NAWCWD Navy Ship Weapons Test Complex at White Sands Missile Range
 - AFFTC, Air Force Flight Test Center
 - New Mexico and the Surface Warfare Engineering Facility
 - Port Hueneme Naval Surface Warfare Center

An FAA-approved low-level route between the Sea Range and the Land Range at China Lake is used for Cruise Missile testing.

⁴⁶¹ <http://www.nawcwpns.navy.mil/~pacrange/r1/Sea.htm#RANGES>

B.8.1.2 History

Mugu beach is believed to be the site where Juan Cabrillo landed on October 10, 1542. "Muwu" was the capital village of the Chumash Indians located along the shores of Mugu Lagoon. Most of its early history centers on ranching, farming, and a famous Mugu fish camp.

During World War II, the Navy began to develop sites where both missiles and pilotless aircraft could be tested. In 1947, Congress appropriated funding to establish a permanent Navy presence at Point Mugu for this purpose. Since the mid-1940's, Point Mugu has had several "Center Names", each having the mission to develop, test, and evaluate missiles and related systems, and for drones to use in naval test programs. Names have included:

- Oct 1, 1946 - U.S. Naval Air Missile Test Center
- Aug 1, 1949 - Naval Air Station
- Jun 16, 1958 - Pacific Missile Range
- Jan 7, 1959 - Naval Missile Center
- Apr 26, 1975 - Pacific Missile Test Center
- Jan 21, 1992 - Naval Air Warfare Center Weapons Division and Naval Air Weapons Station.

In January 1992, the Pacific Missile Test Center was disestablished and the Naval Air Warfare Center Weapons Division was formed, which aligned technical functions with those of the former Naval Air Weapons Center China Lake, California. At the same time the Naval Air Station Point Mugu was disestablished and the Naval Air Weapons Station was commissioned. Today, with a combined military/civilian/contractor team effort, the Point Mugu Naval complex continues to provide development and testing of weapons.

B.8.2 Facilities

B.8.2.1 Major

Major facilities are located at the following:

- Main Base Complex
- San Nicolas Island
- Laguna Peak
- Port Hueneme
- Santa Cruz Island

Main Base Complex - Landside facilities are located in the southeastern corner of the Oxnard Plain in Ventura County, where the plain, the sea, and the Santa Monica Mountains meet. Additional facilities are located on adjacent islands.

The main base complex includes the Naval Air Weapons Station (NAWS) (Figure B.8-3) and Laguna Peak (Figure 3.8-4). Three runways are maintained by NAWS Point Mugu to support Range User operations. The primary runway at the main base is 11,000 feet by 200 feet. The secondary runway is 5,500 feet by 200 feet. A third runway, at SNI, is 10,000 feet by 200 feet. Capabilities also include threat simulation, test and evaluation laboratories, and advanced modeling and simulation.



Figure B.8-3 Point Mugu Main Base



Figure B.8-4 Laguna Peak

San Nicolas Island⁴⁶² – San Nicolas Island [a.k.a. San Nic and SNI], is the most northwesterly of the four southern Channel Islands. Like its eastern neighbor San Clemente Island, San Nicolas is owned and operated by the US Navy. Located 65 NM southwest of the Point Mugu complex, San Nicolas Island (Figures B.8-5 and B.8-6) is the cornerstone of the Sea Range capabilities. It is used as a launch site and as an instrumentation site. It includes deep surrounding waters, a 10,000-foot runway, air terminal, housing, power plant, fuel farm, and instrumentation. Also supported are frequency monitoring, meteorological measurements, and ordnance and launching facilities.

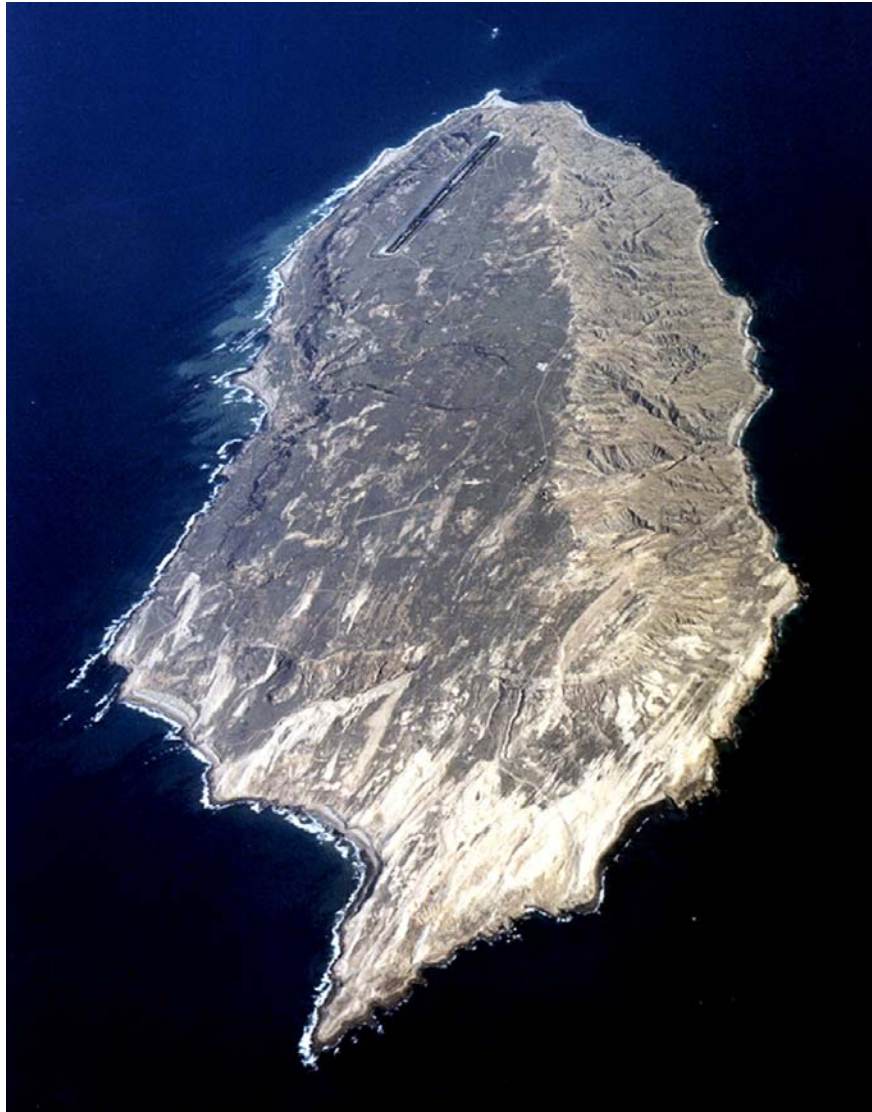


Figure B.8-5 **San Nicolas Island**

⁴⁶² <http://www.globalsecurity.org/military/facility/san-nicolas-island.htm>



Figure B.8-6 **San Nicolas Island Facilities**

Laguna Peak – A 1,500 ft. mountain overlooking the main base, Laguna Peak hosts instrumentation for extended line-of-sight.

Port Hueneme – A deepwater port (35-foot draft) adjacent to Sea Range, it supports range surface craft used for target recovery, security support, surface targets, assists with commercial shipping activities, and supports offshore islands (Figure B.8-7).



Figure B.8-7 **Port Hueneme**

Santa Cruz⁴⁶³ - Santa Cruz Island (SCI) is located approximately 25 NM west of Point Mugu. The largest of California's Channel Islands, it is about 20 miles west of Ventura. Most of the island is owned by the Nature Conservancy, a private organization that has purchased land in California for preservation in its natural state. The remainder is owned by the National Park Service. The Navy leases a mountaintop near the eastern end of the island for an instrumentation complex. The complex is housed on a ten-acre parcel and includes barracks, a power plant, fire station and a heliport. Instrumentation consists of meteorological data collection, secure VHF/UHF radio communications and data transmission, microwave relay to/from VAFB, Laguna Peak and SNI, and surface surveillance radar coverage of the Sea Range.

B.8.2.2 Launch

Launch⁴⁶⁴ facilities are available on the main land at Point Mugu and on San Nicolas Island.

Point Mugu - The surface launching and ordnance facilities at Point Mugu support operations on the Sea Range. A combination of launch pads, blockhouses, ordnance assembly buildings and magazines exist at Point Mugu on the west side of the complex.

The surface-launching complex at Point Mugu consists of the following launch complexes:

- Main
- BRAVO
- CHARLIE

Main – The Main launch complex is the primary launching complex at Point Mugu. It includes eight launch pads and a blockhouse. Each launch pad includes a special rail-type launcher.

BRAVO - The BRAVO launch complex includes two launch pads and a blockhouse. This facility is unoccupied and available for installation of Range User-owned launch equipment. The launch pads are identical, reinforced, 100' x 100' concrete pads. In the past, the launch complex has been used to launch the TOMAHAWK, HARPOON and Japanese Defense Force SSM-1 missiles.

CHARLIE – The CHARLIE complex consists of a blockhouse with a GOW-5 Launch Sequencer and three pads. One pad is a 100' x 127' asphalt/concrete apron and the other two are 51' x 58' concrete pads. A universal rail-type launcher, with a capacity of 4000 pounds, is located on the largest pad. This launcher was formerly used to launch meteorological rockets and the surface launched version of the AMRAAM missile. The other pads are currently unoccupied.

⁴⁶³ <http://www.globalsecurity.org/military/facility/santa-cruz-island.htm>

⁴⁶⁴ <http://www.globalsecurity.org/military/facility/point-mugu.htm>

San Nicolas - The San Nicolas Island launch complex (Figures B.8-8 and B.8-9) is capable of supporting missile (Tomahawk & RAM) and missile target (Vandal) launches. Launch complexes, ordnance handling, and a remote/secure environment provide an ideal location for weapons Test and Evaluation (T&E). Many of the targets routinely used on the Sea Range (the BQM-34 and BQM-74 series and the MQM-8G) are launched from either the Point Mugu Surface Launch Complex at Building 55 or from additional specialized launch facilities on San Nicolas Island.



Figure B.8-8 **San Nicolas Launcher**



Figure B.8-9 **San Nicolas Launch**

B.8.3 Instrumentation

B.8.3.1 Locations

Point Mugu's collection facilities include instrumentation at the following:

- Point Mugu
- San Nicolas Island
- Laguna Peak
- Santa Cruz Island
- Pillar Point

Instrumentation includes the following:

- Radar
- Telemetry
- Optics
- Command
- Timing
- Communication

Ground-based coverage may be augmented by airborne instrumentation, NP-3D Orion aircraft.

Point Mugu - Best telemetry source selection is performed at Point Mugu. The Point Mugu telemetry system uses four GKR-11 and two GKR-13 antennas for primary operational support. The GKR-11 antennas are located near the Telemetry Collection Facility (TCF) (Figure B.8-10). The GKR-13 antennas are located on Laguna Peak and remotely controlled from the TCF at Point Mugu. The antennas operate in multiple modes, and a computer bus system, (Sensor Positioning and Read back System {SPARS}), generates look angles for automatic acquisition and re-acquisition using sensor inputs from other telemetry and radar systems. The Range Communications Control Center (Figure B.8-11) is located at the main base at Point Mugu. Point Mugu has two FPS-16 tracking radars, two surface search radars; a FPS-114 and a SPS-10, and one ASR-7A air search radar.



Figure B.8-10 Point Mugu Telemetry Site



Figure B.8-11 Point Mugu ROCC

San Nicolas Island - San Nicolas Island includes the following instrumentation:

- Metric tracking and surveillance radars (Figure B.8-12)
- Global Positioning Systems (GPS) receivers
- Optics
- Telemetry (Figure B.8-13)
- Communications to support long range and over-the-horizon weapons testing

San Nicolas Island has numerous radars including three FPS-16 and two RIR-716 tracking radars, and one FPS-114 surface and one ARSR-3 air route surveillance radars. San Nicolas Island has extensive telemetry collection facilities including three 30 ft, two 20 ft, one 8-ft, and one 7-ft diameter antennas. Signals can be recorded and routed to the

Point Mugu operations complex for best source selection. The SNI Telemetry Collection Facility also provides real-time reception, recording and relay of telemetry data. SNI supplies this telemetry data to Point Mugu for processing and display. Telemetry signals are received through land-based antennas located at SNI and sent in real-time by a fiber optic cable and/or microwave to Point Mugu. The best source signals are then sent by fiber optic cable to the TDC, located in the Range Operations Center (ROC) for real-time processing and display. The SNI telemetry facilities are ideally located to support operations throughout the Sea Range as well as strategic and space launches from the Western Range (WR), Vandenberg Air Force Base (VAFB). The capability to record and display Miss Distance Indication (MDI) and video Doppler data is also available. Nearly all major users of the Sea Range rely on telemetry support from SNI.



Figure B.8-12 San Nicolas Radar



Figure B.8-13 San Nicolas Telemetry

Laguna Peak⁴⁶⁵ - The Laguna Peak Complex (Figure B.8-14) is located on a 1,500-foot-high mountain peak and is one-half mile east of the main base complex. Laguna Peak provides an elevated line-of-sight location for overlapping coverage of the Sea Range. Laguna Peak provides optics, telemetry, airborne and surface target control, radio communication and data transmission, surveillance radar, and Command Transmitter System (CTS) for Command Destruct. Laguna Peak is a primary site for range safety CTS for all ballistic missile launches from VAFB.



Figure B.8-14 Laguna Peak Complex

Santa Cruz Island - Santa Cruz Island (SCI) is located within the Sea Range approximately 25 NM west of Point Mugu. The Navy leases a mountaintop near the eastern end of the island for an instrumentation complex. The complex is housed on a ten-acre parcel and includes barracks, a power plant, fire station and a heliport. Instrumentation consists of meteorological data collection, secure VHF/UHF radio communications and data transmission, microwave relay to/from VAFB, Laguna Peak and SNI, and surface surveillance radar coverage of the Sea Range.

B.8.3.2 Types

Communications - During a test or training event, voice and data transmissions from the test control rooms are routed to the Range Communications Control Center at the main base at Point Mugu. From there, they are sent via fiber optic cable to Laguna Peak for retransmission to the event participants. Seven high-capacity transmitters and

⁴⁶⁵ <http://www.globalsecurity.org/military/facility/laguna-peak.htm>

transceivers on Laguna Peak handle most of this communication traffic. Another 48 radio transceivers located at Laguna Peak carry most of the routine daily main-base traffic such as vehicle dispatching, maintenance scheduling and operational support. As many as 36 more tactical radios, all operating through Laguna Peak, may be deployed among participants in a range exercise. On the Peak, an impressive array of 90 antennas, most housed in white, weather-resistant domes, support signal transmission and reception. Juggling all these communications is the job of the Technical Control Facility at Point Mugu. The facility's frequency-management specialists ensure that all parties are operating on the correct assigned frequencies. Large, complex test scenarios often require long-range communications with elements outside the Sea Range. When China Lake or Edwards Air Force Base participates in an operation, a microwave station on Laguna Peak links the Sea Range with those sites, transmitting voice and data at 155 megabytes per second. Laguna Peak, from its vantage point more than a quarter mile above the Pacific, has line-of-sight to Burnt Peak in Los Angeles County. A repeater on Burnt Peak relays the microwave signals to Edwards and thence, via the Laurel Peak repeater, to China Lake.

Telemetry⁴⁶⁶ - During range operations, telemetry is the primary method of collecting technical data from ships, aircraft, test items and targets. Laguna Peak's commanding view of the Sea Range makes it an ideal location for telemetry reception. Two 20-foot-diameter dish antennas gather the telemetry signals from the range and transmit them over the fiber-optic cables to Point Mugu's Telemetry Data Center. There they are decrypted (if necessary), processed, recorded, and sent to the Operations Control Room for display. An in-house engineering project completed last year now allows all telemetry functions on the Peak to be operated entirely by remote control from the main base.

Target control - Laguna Peak also has a role in controlling the targets in test and training events. Two 8-foot-diameter dishes at the peak relay signals from the target controllers at the main base to air and surface targets maneuvering on the range. Because some targets are launched directly off the beach at Point Mugu, the antennas, located on the northwest side of the Laguna Peak complex, can look down directly at the launch site. Working in conjunction with four similar tracking antennas on San Nicolas Island, the antennas allow total and continuous control of up to six targets at one time.

Command/Destruct - Laguna Peak also performs command destruct. Should a rocket, missile or target stray off course and pose a potential hazard, the item cannot escape the destruct signal emanating from Laguna Peak. The signal activates an explosive charge or other on-board flight-termination mechanism, the test is ended, and the engineers go back to the drawing board. The Peak also hosts a massive 10-kilowatt command/destruct transmitter installed specifically to support Vandenberg Air Force Base. This transmitter

⁴⁶⁶ <http://www.nawcwpns.navy.mil/~pacrange/s1/news/2001/Laguna.htm>

is used during test of missiles that may travel several thousand miles across the Pacific. It will also be used for Trident tests when that system comes to the Sea Range in 2005.

Naval Satellite Operations Center - The most visually impressive feature on the Peak is a 60-foot-diameter antenna that points straight up. Owned and operated by the Naval Satellite Operations Center, the antenna is part of the Navy's Geodetic Follow-On Satellite System that provides round-the-clock secure oceanographic data to ships at sea. Laguna Peak's equipment also includes an AN/FPS-114 Sea Surveillance Radar used primarily for range clearance prior to live firings, and a GPS station that assists in precision tracking of objects on the Sea Range. The site also has two large concrete pads used as test platforms for developmental seekers and radars.

Radar Reflectivity Lab - The Radar Reflectivity Laboratory at Point Mugu remains in the forefront of radar cross-section (RCS) measurements and radar signature control technology. The facility provides monostatic and bistatic radar signature characterization and diagnostics of test objects. The application of wide-band RCS data to Inverse Synthetic Aperture Radar (ISAR) imaging of complex objects was pioneered at the laboratory in the 1970s, and is used to conduct signature diagnostics for a variety of applications. The two large anechoic chambers are equipped with compact-range collimating reflectors, which provide far-field measurement conditions. The Bistatic Anechoic Chamber is the only facility of its kind in the world to provide full 180-degree horizontal and 90-degree vertical bistatic RCS measurements. All chambers can accommodate a wide variety of test items including tactical airborne missiles.

B.9 SEA LAUNCH

B.9.1 Background

B.9.1.1 General

Sea Launch is the world's only ocean-based launch service⁴⁶⁷. Conceptually, it involves just two ships. One ship is the launch platform and the other contains the control room and personnel quarters. The launch platform and command ship are transported to an equatorial launch site (Figure B.9-1) where the missile is readied. Prior to launch, the command ship is backed off a few miles to a safe location and the launch sequence is initiated (Figure B.9-2).

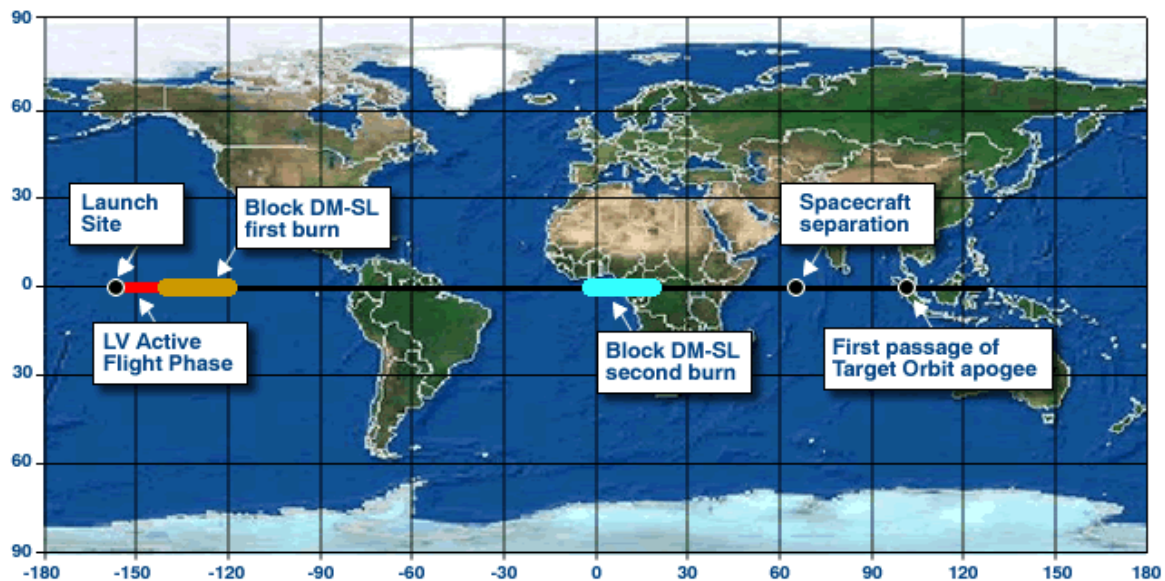


Figure B.9-1 Sea Launch Ground Track

⁴⁶⁷ <http://www.sea-launch.com/>



Figure B.9-2 Sea Launch Lift Off

The Sea Launch operation is based out of Long Beach, CA. Its launch site is normally in the Pacific Ocean at the equator, 154 degrees West Longitude. Even though the launch site lies in international waters, per international treaty, the host country (determined by the home port) is responsible for licensing the launch. For Sea Launch, the FAA is responsible for granting the licenses necessary to launch.

The international partnerships for Sea Launch include:

- Boeing - (40%) Payload fairing, spacecraft integration, mission operations
- RSC Energia (Russia) - Block DM upper stage, launch vehicle integration and mission operations
- SDO Yuzhnoye/PO Yuzhmash (Ukraine) - First two Zenit-3SL stages, launch vehicle integration support and mission operations
- Anglo-Norwegian Kvaerner Group (Norway) - Design and construction of the *Odyssey* Launch Platform and the *Sea Launch Commander*

Using an equatorial launch site provides commercial satellite customers with the most direct and cost-effective route to geosynchronous transfer orbit. From an equatorial launch site, a rocket can lift a heavier spacecraft mass or place a payload into a higher perigee, helping satellite operators to attain a longer satellite service capability.

Once a payload has been thoroughly checked out by customer technicians, the encapsulated payload is rolled out to the Assembly and Command Ship (ACS) and integrated with the launch vehicle. Vehicle and spacecraft segments are mated with the launch vehicle in a horizontal orientation. The fully integrated launch vehicle is then transferred by an onboard crane system from the ACS to the Launch Platform.

B.9.1.2 History

Sea Launch was authorized in April 1995 after two years of studies and discussions. Ship construction began in December 1995. The Assembly and Command ship (*Sea Launch Commander*) was completed in Govan Shipyard in Glasgow, Scotland in November 1996. The launch platform (*Odyssey*) was refurbished at the Rosenberg Shipyard in Stavanger, Norway in May 1997. Both ships received additional modifications in Russia in 1998. The first demonstration launch occurred in March 1999 and the first commercial launch occurred in October 1999.

B.9.2 Facilities

Major facilities include the following:

- Home Port
- Assembly and Command Ship (ACS)
- Launch Platform (LP)

Home Port – The homeport (Figures B.9-3 and B.9-4) is Long Beach, California. The homeport is used to transfer the horizontally integrated rocket to the Launch Platform



Figure B.9-3 Sea Launch Base Facilities



Figure B.9-4 Home Port

ACS – The custom-built Assembly and Command Ship (*Sea Launch Commander*, Figure B.9-5) is an all-new, specially-designed vessel that serves as a floating rocket assembly factory while in port; and when at sea, provides crew and customer accommodations. It also houses mission control facilities for launches at sea. The ACS is 660 feet long, 106 feet wide, with a displacement of 34,000 tons and has a range of 18,000 nautical miles. The ACS provides accommodations for up to 240 crewmembers, customers and VIPs — including medical facilities, dining room, recreation and entertainment facilities.

The Launch Control Center (Figure B.9-6) is located on the ACS with special units of operations for English-speaking and Russian-speaking launch teams. Operations are managed in two-way translation services. All countdown, launch, telemetry and tracking data are observed and directed from this center.

LP – The Launch Platform (*Odyssey*) (Figure B.9-7) is a refurbished former North Sea oil drilling platform. The vessel is one of the largest semi-submersible, self-propelled vessels in the world at 436 feet long, 220 feet wide, with an empty draft displacement of 30,000 tons, and a submerged draft displacement of 50,600 tons. It provides accommodations for 68 crew and launch system personnel – including living, dining, medical and recreation facilities.



Figure B.9-5 Sea Launch Commander



Figure B.9-6 Launch Control Center

It is equipped with a large, environmentally controlled hangar for storage of the Sea Launch rocket during transit, and with mobile transporter/erector equipment that is used to roll out and erect the rocket in launch position prior to fueling and launch. Special facilities onboard enable the storage of rocket fuels (kerosene and liquid oxygen) sufficient for each mission.



Figure B.9-7 Launch Platform

B.9.3 Instrumentation

Instrumentation⁴⁶⁸ is used throughout the countdown, special monitoring systems measure actual loading conditions on the spacecraft and on the rocket itself to insure that changes in the wind and sea do not cause excessive loads on critical systems. Trending information allows time for the launch team to take corrective actions if large swells or wind gusts develop.

Sea Launch uses line-of-sight radio frequency telemetry links at lift-off, and then depends on a combination of the NASA Telemetry and Data Relay Support Systems (TDRSS), and INTELSAT. These communication satellites are linked to ground stations in the Western United States, Europe, Russia and the Ukraine to provide sensor information about the launch vehicle and payload unit back to the Commander to track the progress of the mission.

⁴⁶⁸ <http://www.sea-launch.com/special/sea-launch/services.htm>

B.10 POKER FLATS

B.10.1 Background

Poker Flat Research Range is a university-owned range located approximately 30 miles north of Fairbanks, Alaska (Figure B.10-1). It is operated by the University of Alaska's Geophysical Institute under contract to NASA's Wallops Flight Facility. Poker Flat is used for launching sounding rockets. In addition, Poker Flat also houses many scientific instruments designed to study the arctic atmosphere, aurora borealis and ionosphere.⁴⁶⁹

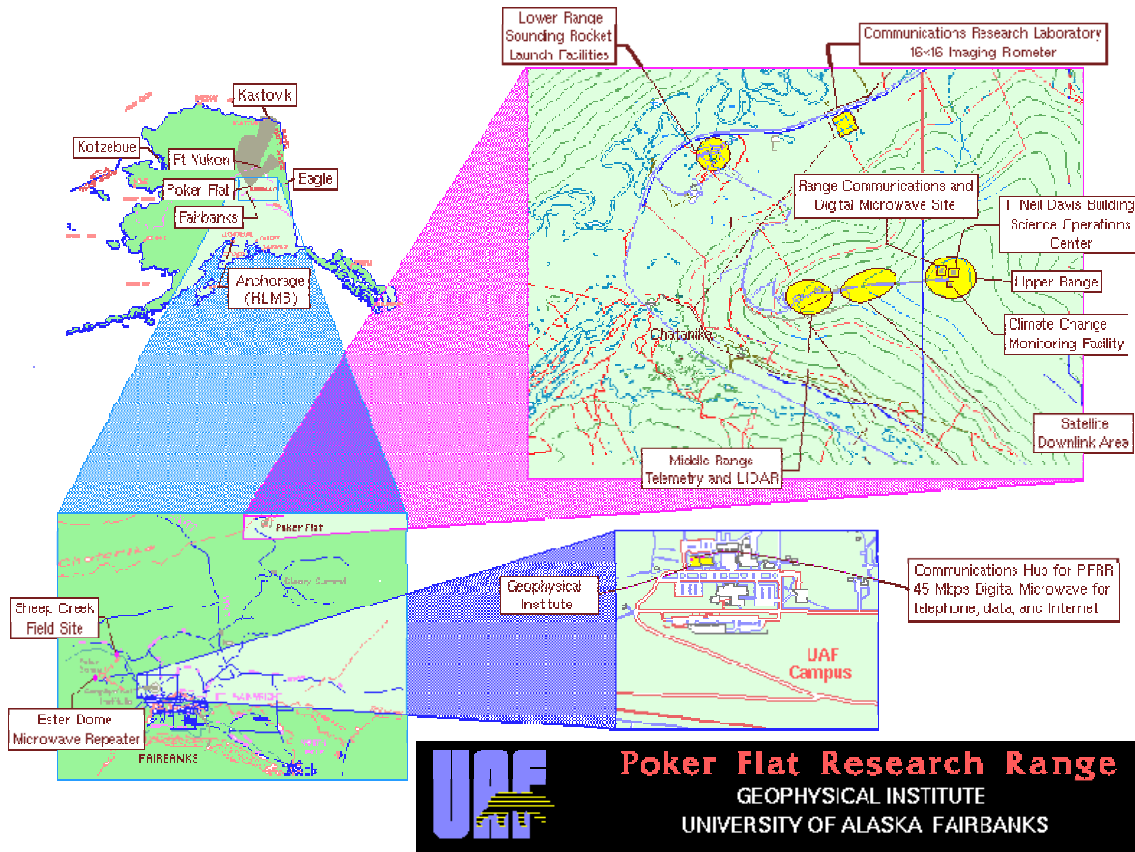


Figure B.10-1 Poker Flat Research Range

B.10.2 Facilities

Poker Flat is divided into a Lower, Middle and Upper range.

⁴⁶⁹ <http://www.pfrr.alaska.edu/>

Lower Range

The Lower range contains the administrative facilities and launch facilities. There are five sounding rocket launchers (Figure B.10-2), a test rocket launcher, and a launcher-mountable tube for sending up meteorological rockets.



Figure B.10-2 Sounding Rocket Launcher

Most of the rocket launchers rotate so that the rocket may be loaded in the horizontal position and then rotated upwards for launch. Two of the launch sites have weather enclosures (Figure B.10-3). Poker Flat can handle rockets up to 60 ft long.



Figure B.10-3 Poker Flat Launcher Enclosure

Middle Range

The Middle range contains scientific, telemetry, and tracking facilities on a ridge overlooking the lower range. It includes the Lindar Observatory and the Transportable Orbital Tracking Systems (TOTS) (Figure B.10-4).



Figure B.10-4 **Poker Flat Telemetry Systems**

Upper Range

The upper range contains more scientific and support facilities on a hilltop above the lower and middle ranges. Facilities include:

- Communications and Surveillance Radar facilities
- Climate Change Monitoring station
- T. Neil Davis Science Operations Center

B.10.3 Instrumentation

Instrumentation includes the following:

- Radar
- Telemetry
- Optics
- Communication
- Weather

Radar – Surveillance radar is located in the upper range area.

Telemetry – Telemetry systems are located in the middle range area.

Optics – Optic sites are located in the middle range area

Communication – Communication systems are located in the upper range area.

Weather – Weather systems are located in the upper range area.

B.11 PACIFIC MISSILE RANGE FACILITY

B.11.1 Background

B.11.1.1 General

The Navy's Pacific Missile Range Facility (PMRF) is located on the island of Kauai in Hawaii (Figure B.11-1). Kauai is the northernmost of the inhabited islands of Hawaii. It is located 95 miles northwest of Oahu. It is roughly circular in shape, with a diameter of 32 miles and an area of 55 square miles. PMRF is the world's largest multi-environment range, capable of supporting tests and operations in the following environments:⁴⁷⁰

- Surface
- Subsurface
- Air
- Space

The headquarters and primary operations are located on 1800 acres on the western shore of Kauai at Barking Sands (Figure B.11-2). The nearest town, Kekaha, is eight miles southeast. Supporting instrumentation sites are at:

- Makaha Ridge
- Kokee Park

These sites overlook the vast ocean range areas to the west and north of Kauai. PMRF contains thousands of square miles of underwater range and over 42,000 square miles of controlled airspace (Figure B.11-3).

PMRF provides a full spectrum of instrument range support, including:

- Radar
- Telemetry
- Communications
- Command & Control
- Underwater instrumentation
- Electronic warfare
- Launching facilities
- Data processing & display
- Target/weapon launching and recovery facilities⁴⁷¹

⁴⁷⁰ <http://www.acq.osd.mil/te/pubfac/pmrf.html>

⁴⁷¹ <http://www.globalsecurity.org/military/facility/pmrf.htm>



Figure B.11-1 Map of Kauai



Figure B.11-2 PMRF Main Base



Figure B.11-3 PMRF Range

PMRF's mission is to provide range services to facilitate training, tactics development, and evaluation for air, surface, and subsurface weapon systems for PACFLT, other DoD agencies, and foreign military forces; and to maintain and operate facilities and provide services and materials to support operation of aviation activities and units of the operating force of the Navy, and other activities and units designated by the Chief of Naval Operations.

PMRF often operates with other Agencies, Laboratories, Ranges and Bases. These include the following:

- Western Test Range
- Sandia National Laboratory Kauai Test Facility (KTF)
- University of Hawaii research facilities in Oahu
- Wheeler Army Base, Oahu
- Hickham AFB, Oahu
- Pearl Harbor Navy Base, Oahu
- Sandia Maui Haleakala Facility
- Air Force Maui Optical Station (AMOS)
- Maui Optical Tracking and Identification Facility (MOTIF)
- Ground-based Electro-optical Deep Space Surveillance System (GEODSS)
- Maui Space Surveillance Site (MSSS)
- Hawaii Tracking Station, Kaena Point, Oahu

KTF is collocated with PMRF.

B.11.1.2 History

Kauai is believed to be the oldest of the inhabited Hawaiian Islands, being the first of a chain of volcanic mountains to erupt from the sea and the first to become extinct. It was probably inhabited over 1,000 years before Captain Cook's landed at Waimea on January 19, 1778.

In 1921, Barking Sands was acquired by the Kekaha Sugar Company from the Knudsen family. On occasion, private planes would land and take off from the grassy field used for pasture. In 1932, an Australian named Kingsford Smith made a historic flight from Barking Sands to Australia in a Ford Trimotor.

The U.S. Army acquired 549 acres in 1940, including the grass landing field. The Army paved the landing strip and the installation became known as "Mana Airport." In June 1941, additional acreage was obtained, bringing the total up to 2,058 acres. Hawaiian Airlines and Pan American Airlines landed at the field. Lihue Airport was completed in 1949. During World War II, Barking Sands experienced heavy use by military traffic. The site went through numerous name changes: Mana Airport, Mana Airfield Military Reservation, Barking Sands Military Reservation, Kekaha Military Reservation, Barking Sands Airfield, Bonham Airfield, Bonham Air Force Base, Bonham Air Base, and Auxiliary Landing Field (ALF) Bonham.

In 1948, Barking Sands Military Reservation was declared as excess; however, the Air Force disapproved the recommendation and obtained additional acreage. In 1954, the name of the base was officially changed to Bonham Air Force Base.

In 1956, the Navy came to Barking Sands (Bonham AFB), through a joint utilization license. In November 1958, the Pacific Missile Range Facility was formally established. In 1964, 1,885 acres of Barking Sands were transferred to the Navy and in 1966, Barking Sands was transferred within the Navy to the Commanding Officer, Pacific Missile Range, and renamed, "Pacific Missile Range Facility, Barking Sands." By this time, PMR had established a chain of stations throughout the Pacific. Besides Barking Sands and Kokee, several downrange stations under PMR included South Point, Hawaii; Midway Island; Wake Island, Eniwetok Atoll; Tern Island; Christmas Island; Canton Island; and the recovery ships, *USNS Longview* and *USNS Sunnyvale*.

In 1967, the Barking Sands Tactical Underwater Range (BARSTUR) and the Makaha Ridge Instrumentation Site were completed. In 1968, the Command Headquarters, Pacific Missile Range Facility, Hawaiian Area was established at Barking Sands. Facility improvements and expansions continued through 1974. With changing requirements, most of the "downrange" facilities were later closed or transferred.^{472, 473}

⁴⁷² <http://www.pmr.f.navy.mil/>

⁴⁷³ <http://www.globalsecurity.org/military/facility/pmr.f.htm>

B.11.2 Facilities

PMRF and other facilities are described below:

Barking Sands - Barking Sands contains the following functions:

- Main PMRF operations area
- Range Control
- Operation Control Center
- Tracking and Surveillance radars
- Data Processing
- Communication hub
- Launch Area
- Air Field

Rocket launch services are provided by Sandia's Kauai Test Facility. The PMRF/KTF is recognized in the Anti-Ballistic Missile (ABM) Treaty as an authorized site for STARS missile launches.

Makaha Ridge – This 1800-foot site eight miles north of Barking Sands provides the following:

- Tracking & surveillance radars
- Telemetry receivers & recorders
- Frequency monitoring
- Electronic warfare
- Communications

Kokee Park – This site is 12 miles northeast of Barking Sands and has an altitude of 3400 feet. It contains the following:

- Tracking radars
- Telemetry
- Communication
- Command and Control

Niihau – This privately owned island has the following:

- Remotely operated surveillance radar
- Test vehicle recovery site
- Electronic warfare (EW)
- EW portable simulators
- Helicopter terrain flight training course

Sandia Maui Haleakala Facility – Provides the following:

- Telemetry receiving/recording
- Flight following
- Command control and flight termination

Maui Space Surveillance Site – The MSSS (Figure B.11-4 & B.11-5) atop 10,000-foot Mount Haleakala, contains multiple optic sites. Its relatively stable climate of clear, dry air, with low levels of particulates and minimal light pollution provides a unique vantage point for observing sub-orbital vehicles.⁴⁷⁴ Included at this site are the following:

- Air Force Maui Optical Station (AMOS)
- Maui Optical Tracking and Identification Facility (MOTIF)
- Ground-based Electro-optical Deep Space Surveillance System (GEODSS)

MSSS is the only site of its kind in the world, combining operational satellite tracking facilities (MOTIF and GEODSS) with a research and development facility (AMOS)⁴⁷⁵.



Figure B.11-4 Maui Space Surveillance Site

⁴⁷⁴ http://ulua.mhpcc.af.mil/AMOS/Photos/msss_o2.jpg

⁴⁷⁵ <http://www.fas.org/spp/military/program/track/msss.htm>



Figure B.11-5 Maui Space Surveillance Site (close up)

Hawaii Tracking Station – This site at Kaena Point, Oahu, provide real-time telemetry and metric and signature tracking data to PMRF via the Hawaii Digital Microwave System (HDMS).

B.11.3 Instrumentation

Range instrumentation sites (Figure B.11-6) are located at:

- Makaha Ridge
- Kokee Park

Additional instrumentation is provided by other agencies on adjacent islands.



Figure B.11-6 PMRS Instrumentation Site

B.11.3.1 Radar

PMRF provides space, air, and surface tracking using precision-tracking radar sites at elevations of 75 ft., 1700 ft., and 3800 ft. Radars are provided at the following locations:

- Barking Sands, Kauai
- Makaha Ridge, Kauai
- Kokee Park, Kauai
- Niihau Island
- Kaena Point, Oahu

Barking Sands – Tracking and surveillance radars

Makaha Ridge – Tracking and surveillance radars

Kokee Park – Tracking radars

Niihau Island – Remotely operated surveillance radar

Kaena Point - This site on the northwest end of Oahu contains an FPQ-14 radar operated by the 30th Range Squadron. It provides metric and signature tracking data to PMRF via the HDMS. The Kaena Point C-band radar supports the test and evaluation of U.S. ICBM and space launches. As an ancillary mission, this radar spends approximately 128 hours a week supporting the space surveillance mission.⁴⁷⁶

B.11.3.2 Telemetry

Telemetry support is provided at:

- Makaha Ridge, Kauai
- Kokee Park, Kauai
- Niihau Island
- Kaena Point, Oahu
- Haleakala facilities on Maui

Makaha Ridge – This location contains the primary telemetry receivers and recorders.

Kokee Park – Contains a telemetry receiver.

Kaena Point - The Hawaii Tracking Station, located at Kaena Point, Oahu, provides real-time telemetry data to PMRF via the HDMS.

B.11.3.3 Optics

⁴⁷⁶ http://www.fas.org/spp/military/program/nssrm/initiatives/x_kaena.htm

Optic sites are located at the Maui Space Surveillance Site (MSSS) atop 10,000-foot high Mount Haleakala. This site contains the following:

- Air Force Optical Station (AMOS)
- Maui Optical Tracking and Identification Facility (MOTIF)
- Ground-based Electro-optical Deep Space Surveillance System (GEODSS)

AMOS – The Maui Space Surveillance System, also known as AMOS by the scientific community, is an asset of the US Air Force Materiel Command's Phillips Laboratory.⁴⁷⁷ The mission of AMOS is to conduct research and development of new and evolving electro-optical sensors, as well as to provide support for operational missions defined by US and AF Space Command. In addition, AMOS provides experiment support to a wide variety of military and civilian organizations in diverse fields. This support has included the Strategic Defense Initiative Organization (SDIO), the National Aeronautics and Space Administration (NASA), the Jet Propulsion Laboratory (JPL), and many universities. AMOS has hosted and supported a wide variety of visiting experiments. This is a state-of-the-art electro-optical facility combining operational satellite tracking facilities with a research and development facility. It houses DoD's largest telescope, the 3.67-meter Advanced Electro Optical System (AEOS) [Figure 3.11-7], as well as several other telescopes ranging from 0.4 to 1.6 meters⁴⁷⁸.

Typical AMOS visiting experiments include:

- Support for tactical and strategic missile launches out of both Vandenberg and Kauai
- Detection and tracking of orbital debris
- Observations of shuttle and satellite special operations
- Laser illumination of satellites
- Atmospheric physics
- Space sciences and astronomy

MOTIF – The Maui Optical Tracking and Identification Facility is used for tracking and identifying objects.

GEODSS - The Ground-Based Electro-Optical Deep Space Surveillance (GEODSS) site at Maui, Hawaii (Figure 3.11-8) is one of three operational sites performing ground-

⁴⁷⁷ <http://ulua.mhpcc.af.mil/AMOS/mission.html>

⁴⁷⁸ <http://ulua.mhpcc.af.mil/amos.html>

based optical tracking of space objects. The Socorro (New Mexico, USA), Choe Jong San (South Korea) and Maui (Hawaii, USA) sites were all operational by 1983. A fourth site, Diego Garcia (Indian Ocean), was completed in 1987, and a fifth site was planned for Portugal, but later cancelled. The South Korean site was closed in 1993 because of weather and cost concerns⁴⁷⁹. The GEODSS system can track space objects as small as a basketball between 5,500-37,000 km.



Figure B.11-7 **AEOS Telescope**

⁴⁷⁹ <http://www.fas.org/spp/military/program/nssrm/initiatives/maui.htm>



Figure B.11-8 Maui GEODSS Site

B.11.3.4 Command

Operations control is located at Barking Sands. Command Control and flight termination are provided at Kokee Park and on Maui at the Sandia's Haleakala facility.

B.11.3.5 Communications

Communication facilities are located at Barking Sands and Mokaha Ridge. Communication infrastructure includes a local area network utilizing fiber optic lines. Connectivity is provided to CONUS ranges, labs and other facilities to enable data sharing. The Hawaii Air National Guard provides O&M of the Hawaii Digital Microwave System (HDMS). Wheeler Network Communications Control (WNCC) is a major communications hub for PMRF. Voice and data signals are relayed through the HDMS to the WNCC from Mount Kaala, and are further distributed to other military and commercial communications networks. Hawaiian Telephone Company provides a dedicated T1 data link on the FTS2000 network from Barking Sands to AT&T on Oahu, which provides CONUS interconnectivity to the Naval Warfare Assessment Division (NWAD), Corona, California. This link provides the capability for data reduction at NWAD and for nationwide video teleconferencing.

B.12 EGLIN**B.12.1 Background****B.12.1.1 General**

Eglin AFB is the largest military base in Florida and one of the US Air Forces' largest. It is located in the Florida panhandle, close to Ft. Walton Beach and Destin (Figure B.12-1). Eglin is a test center for Air Force precision guided munitions including air-to-air, air-to-ground, and cruise missiles. Eglin has served the U.S. for a period spanning five wars. Currently the Air Armament Center tests and evaluates non-nuclear munitions, electronic combat systems and navigation/guidance systems.

Eglin's mission is to provide responsive and comprehensive test and evaluation to support development of non-nuclear armaments for the Air Force, to provide support for operational training of armament and other electronic warfare systems, and to provide test and evaluation of aerospace navigation and guidance systems⁴⁸⁰.



Figure B.12-1 Location of Eglin

Eglin hosts some 50 associate units representing virtually every major command including the Air Force Special Operations Command (at Hurlburt Field), the U.S. Army Ranger Camp, the U.S. Navy Explosive Ordnance Disposal School and a unit of the Federal Prison System. Eglin includes more than 724 square miles of land ranges and facilities and more than 86,500 square miles of water ranges in the Gulf of Mexico. Eglin Main hosts the main testing, administrative and living facilities along with the major airfield. The Eglin land reservation consists of 27 ranges and 10 auxiliary fields,

⁴⁸⁰ <http://www.acq.osd.mil/sts/te/pubfac/eglin.html>

most being built during the 1930s and 1940s. Today, three airfields remain active: Eglin Main, Duke Field and Hurlburt Field. The original fields are shown in Figure B.12-2.

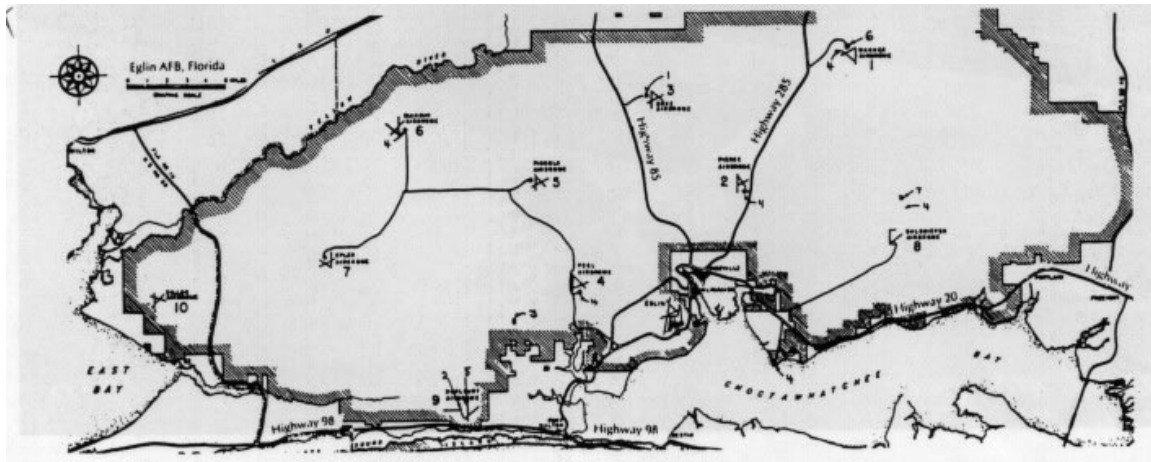


Figure B.12-2 Eglin AFB With 10 Auxiliary Fields

On July 11, 1990, the Munitions Systems Division was redesignated the Air Force Development Test Center (AFDTC). The Center provides test and evaluation support for the development of conventional non-nuclear munitions, electronic combat systems and navigation/guidance systems. In addition to owning and managing the major test complex of land and water ranges at Eglin, the Center manages major range and test facilities at Holloman AFB, NM.

B.12.1.2 History

Early History

Eglin's military history starts around 1931 when the Army Air Corps Tactical School at Maxwell Field, AL, began looking for a new bombing and gunnery range. They saw the potential of the sparsely populated forested areas surrounding Valparaiso, FL, and the vast expanse of adjacent water. A local businessman and airplane buff, James E. Plew, leased 137 acres to the city of Valparaiso on which an airport was established in 1933. In 1934, he offered to donate 1,460 acres to the United States for the bombing and gunnery base. This leasehold became the headquarters for the Valparaiso Bombing and Gunnery Base.

On August 4, 1937, the base was redesignated Eglin Field in honor of Lt. Col. Frederick I. Eglin, U.S. Air Corps, who had been killed in an aircraft crash. On June 27, 1940, the U.S. Forestry Service ceded the Choctawhatchee National Forest to the War Department consisting of some 800 square miles of forest and shore. In 1941, the Air Corps Proving Ground was activated, and Eglin became the site for gunnery training for the Army Air Forces fighter pilots as well as a major testing center for aircraft, equipment, and tactics.

In addition to the testing of all new aircraft and their serial modifications, the Proving Ground Command was especially well suited for special tasks because of the isolation and immensity of the Eglin ranges.

Special Tests

In 1942, Lt. Col. James H. (Jimmy) Doolittle used Eglin to prepare his B-25 crews for an aircraft carrier launched bomber raid against Tokyo. Removing non-essential items from their planes, and practicing until they could safely launch within the physical runway confines that would exist aboard a carrier at sea, the crews practiced at Eglin until they could repeatedly and safely take off.

In 1944, the tactics and techniques for the destruction of German rocket installations were developed at Eglin.

Late in WW-II, Eglin was the site of tests to develop procedures for bombing fire raids against Japan. A "Little Tokyo" was constructed at Eglin for the purpose of verifying the effectiveness of incendiaries against Japanese wooden houses.

In 1970, Eglin served as the training site for the Son Tay Raiders, the group who made the daring attempt to rescue American POWs from a North Vietnamese prison camp.

In 1991, during the Iraq/Kuwait war, Eglin served in the development of the GBU-28 "bunker buster" bomb. On Feb. 27, 1991, the GBU-28 was dropped over Iraq. The cessation of hostilities was announced the next day.

Refugees

With its large territory, Eglin has often been assigned the job of processing and housing refugees. In 1975, a "Tent City" was established at Field Two to house and process more than 10,000 Vietnamese refugees who had fled to the United States at the end of the Viet Nam war.

In 1980, Eglin again became a refugee-processing center for the resettlement of more than 10,000 Cuban refugees.

Missiles

The Eglin facility served as a pioneer in missile development. During 1944 and 1945, American JB-2 missile testing was conducted at Eglin. Parts of some of the old command bunkers, launch ramp, and wrecks still remain⁴⁸¹. This area is now a National Historic Site. The JB-2 missiles were copies of the German V-1 missiles (Figure B.12-3), which terrorized London during WW- II. The JB-2 was developed by duplicating V-1 parts recovered from crash sites in Europe and England. This site reflects early U.S. efforts to develop and test the predecessors of today's cruise missiles.

⁴⁸¹ <http://www.eglin.af.mil/em/virtualtours/jb2/index.htm>

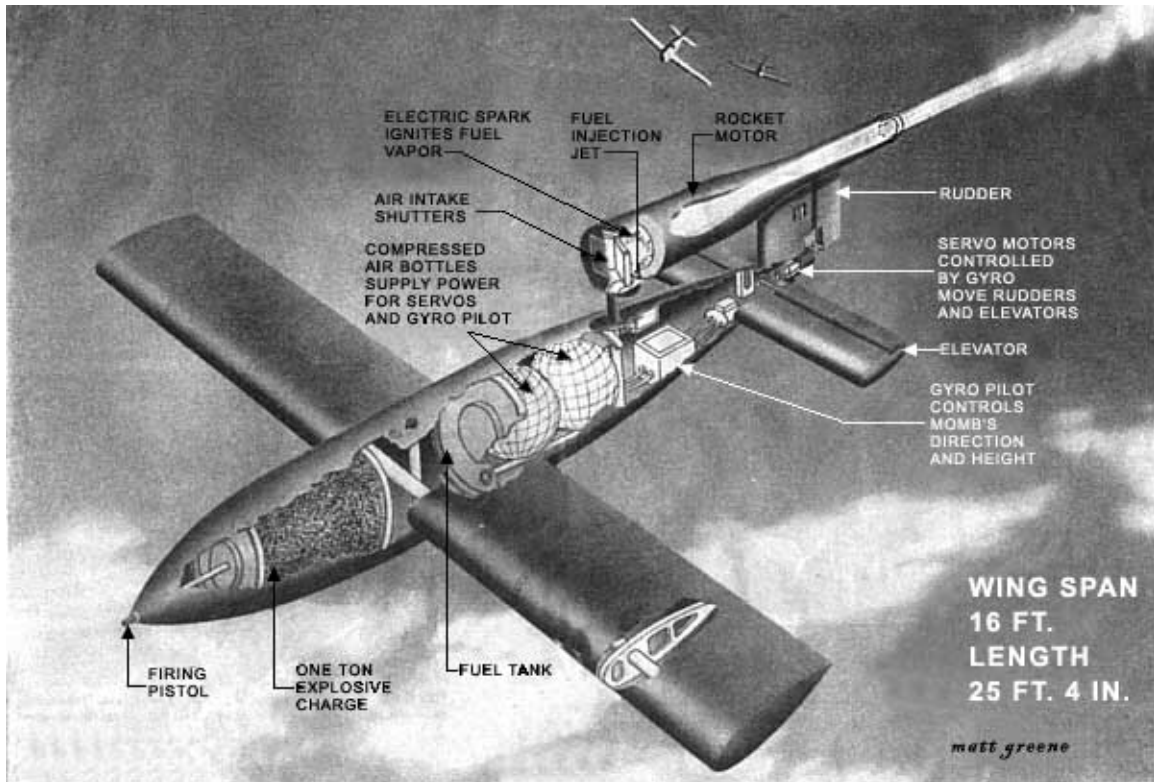


Figure B.12-3 German V-1 Rocket (WWII)

Eglin activated the First Experimental Guided Missiles Group in early 1946, developed the techniques for missile launching and handling, established training programs, and monitored the development of a drone (or pilotless aircraft) capability to support the Atomic Energy Commission tests, in Operation CROSSROADS.

In 1949, the 1st Guided Missiles Squadron was assigned air-to-surface missiles and guided bombs (e.g., TARZON) and the 2nd Guided Missiles Squadron worked with surface-to-surface missiles and aircraft drones. During the first ten months of its existence, the 550th Guided Missiles Wing also continued its predecessor's earlier preparations to support Project GREENHOUSE with drone aircraft⁴⁸².

In 1950, missile units were reassigned from the Air Proving Ground to the Long Range Proving Ground Division (Cape Canaveral). The 1st Guided Missiles Squadron and other missile units did not wind up at Cape Canaveral just because they needed a longer range to test their missiles. If that had been the only concern, missile units could have continued as tenants at Patrick and merely reported to a higher headquarters at Eglin. The longer test range was an important consideration, but missile units were assigned to the Long Range Proving Ground Division because it was a new intermediate headquarters *specifically designed* to support guided missile test programs that were emerging as weapon systems in their own right. As ARDC refocused the Air Force's R&D effort, it

⁴⁸² <http://www.fas.org/spp/military/program/6555th/6555c1en/htm#EN17>

made Cape Canaveral the principal launch site for surface-to-surface and surface-to-air missiles. For the most part, "armaments" remained at Eglin or Holloman.

On December 1, 1957, the Air Proving Ground and the Air Force Armament Center combined to form the Air Proving Ground Center. The Center built the highly instrumented Eglin Gulf Test Range, and for the next few years was a major missile test center.

The BOMARC test program was initially started at Cape Canaveral's Air Force Missile Test Center (AFMTC). The AFMTC's safety agencies ensured that safety requirements for the 15,000-pound 47-foot-long missile were enforced. Seventy BOMARCs were launched from the Cape between September 10, 1951 and April 15, 1960. The program was then transferred to the Eglin (Air Proving Ground Center's) test site at Santa Rosa Island, near Fort Walton Beach, FL.⁴⁸³

On March 15, 1989, the Armament Division was redesignated the Munitions Systems Division. MSD placed into production the Advanced Medium Range Air-to-Air Missile, developed jointly by the U.S. Navy and the Air Force. Other developments include precision-guided munitions, anti-armor weapon systems, and improved hard target weapons.

In recent years, the Cape San Blas facility has been used to launch Patriot missiles and has served as a launch site for the Florida Spaceport Authority.

B.12.2 Facilities

Being an Air Force Base, Eglin has the standard base facilities for headquarters, housing, meals, recreation, security, etc. Since Eglin is host to over 50 other agencies, it has additional offices, laboratories and other facilities to meet these agencies' needs. In addition, Eglin has the following unique facilities:

- Auxiliary Air Fields (10)
- McKinley Climatic Laboratory
- CCF, ASTE, EMTE
- Gulf Test Range
- PRIMES, GWEF
- Test Aircraft
- Kinetic Kill Vehicle HWIL simulation Facility
- Electromagnetic Munition Experimentation Facility

⁴⁸³ <https://www.patrick.af.mil/heritage/45thHist/MIL.htm>

Auxiliary Air Field – There are 10 auxiliary airfields at Eglin. Most were built during the 1930's and 1940's. Only three are still actively used for aircraft. Others have been utilized for refugee sites and tenant organizations.

McKinley Climatic Lab – This facility was conceived during WW II and completed in 1947. This site provides facilities for all weather testing of weapons and ancillary equipment to ensure their function regardless of climatic conditions. The large hangar laboratory can recreate nearly every weather condition that exists on Earth with temperatures ranging from minus 70 to plus 180 degrees Fahrenheit. The hangar was originally designed to hold two B-29s.⁴⁸⁴ It can test aircraft in any operational condition, except flying. Every aircraft in the current DoD inventory has undergone testing in the McKinley Climatic Lab (Figure 3.12-4).⁴⁸⁵ Tests are performed not only on aircraft systems, but also on refrigeration, insulation, instrumentation, surveillance, and control systems. Past tests have included space shuttle tiles, oceanic buoys, de-icing fluids for aircraft wings, electrical contacts under icing conditions, and arctic personnel survival. Ten chambers built in addition to the main hangar include a temperature and humidity room, salt-test room, and rooms for wind, rain, dust, desert, tropic, and jungle climates. This facility is now a National Historic Site.



Figure B.12-4 F-22 Under Test in the McKinley Climatic Lab

⁴⁸⁴ <http://www.asme.org/history/roster/H116.html>

⁴⁸⁵ <http://www.eglin.af.mil/em/virtualtours/mckinley/index.htm>

CCF – The Central Control Facility contains a full range of state-of-the-art computing capabilities. It is used to support in-depth analysis and provides the capability for real-time control during simultaneous test missions.⁴⁸⁶

ASTE – The Armament Systems Test Environment consists of 724 square miles of varied multi-environmental land area with 45 test areas, 34 test systems/facilities, and 26 multipurpose systems/facilities for testing and evaluation of munitions and weapons systems. The major test areas are Air-to-Ground Ranges, Gun Test Facilities, Electro-optical/Millimeter Wave (MMW) Evaluation, Fuse Test Facility, Static Warhead Test Arenas, Kinetic Energy munitions Test Facility, and Security Systems Test Facility.

EMTE – The Electromagnetic Test Environment is an extensive open-air test range providing over-land and over-water weapon effectiveness testing for munitions and electronic combat systems. Specialized testing includes characterization and effectiveness testing, foreign material exploitation, signature measurement, and air-to-air and air-to-ground munitions in an Electronic Combat (EC) environment. The EMTE open-air test capability can be electronically linked with the simulation facilities, e.g., the PRIMES, REDCAP, and AFEWES for realistic multi-threat testing.

Gulf Test Range – This range encompasses 98,000 square miles of the Gulf of Mexico. This area is used for long-range, all altitude, air-to-air or surface-to-air/drone target engagements and long-range or anti-ship air-to-surface weapons evaluations. The Gulf Test Range is also used as a maneuvering area for electronic combat missions on the EMTE.

PRIMES – The Preflight Integration of Munitions and Electronic Systems consists of a fighter-sized anechoic chamber and six shielded laboratories providing secure, realistic testing in a controlled RF environment to support one-on-one and many-on-one tests in static or dynamic flight simulation conditions.

⁴⁸⁶ <http://www.acq.osd.mil/te/pubfac/eglin.html#Location>



Figure B.12-5 PRIMES Anechoic Chamber

GWEF – The Guided Weapons Evaluation Facility provides multi-spectral laboratory simulation support for developing and testing precision-guided weapon technology. GWEF is the only facility of its kind among the United States or its Allies able to test the complete spectrum of weapon seekers under one roof. The GWEF and PRIMES facilities are linked with fiber optic cable; allowing an aircraft to "fly and launch a weapon" from the PRIMES facility while the weapon engages a target in a GWEF simulated combat environment.

Gun Testing - Ground Testing of Gun Systems is conducted at three test areas within the Eglin complex. The type of ammunition and/or the type of target determines which test area will be used. Each test area has the capability to collect the following types of data: muzzle velocity, projectile yaw, chamber pressure, relative action time, dispersion, barrel temperature, and meteorological conditions.⁴⁸⁷

Test Aircraft - Eglin provides a representative cross section of the operational Air Force fighter inventory (F-15, F-16). These aircraft have a standard programmable digital instrumentation system and can be modified for unique project requirements.⁴⁸⁸

⁴⁸⁷ <http://www.acq.osd.mil/te/mrtfb/commercial/afdtc/gun.html>

⁴⁸⁸ <http://www.acq.osd.mil/te/mrtfb/commercial/afdtc/index.html#TCnF>

Kinetic Kill Vehicle HWIL Simulation Facility – This facility (Figure B.12-6) provides a national resource for nondestructive Hardware-In-the-Loop (HWIL) performance evaluation of conventional tactical guided weaponry and endo/exo-atmospheric interceptor systems and subsystems. Digital and HWIL simulators realistically simulate launch-to-impact scenarios for guided weapons.⁴⁸⁹

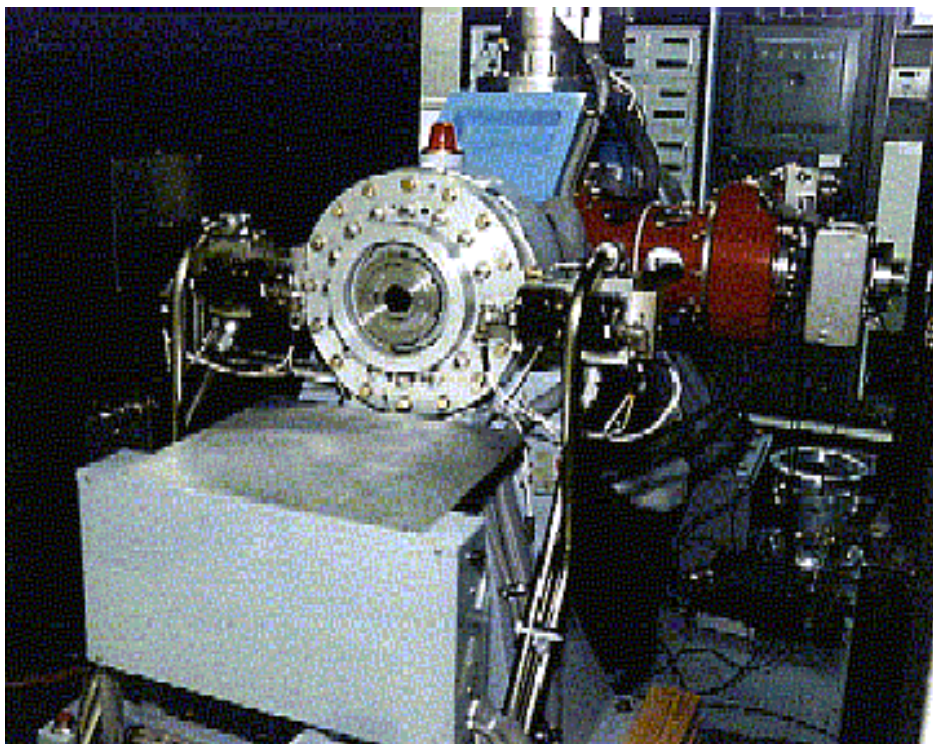


Figure B.12-6 Kinetic Kill Vehicle KWIL Simulation Facility

Electromagnetic Munition Experimentation Facility – This facility (Figure B.12-7) explores advanced munitions concepts, which exploit the unique qualities of electromagnetics, develop advanced oxidation techniques to destroy hazardous compounds generated by munitions development/disposal, and study the gas dynamic principles governing shock-induced combustion/detonation.⁴⁹⁰ The facility has two pulse power supplies in two separate bays. One bay contains a 4.8 million joule capacitor bank that operates at 11,000 volts and can deliver in excess of 2.5 million amperes of current for up to 0.1 seconds. The second bay houses a multi-shot pulse power supply comprised of a capacitor bank charged by a rack of batteries. The multi-shot pulse power supply provides the only true multi-shot electromagnetic launcher test bed available in the world.

⁴⁸⁹ http://www.wrs.afrl.af.mil/infores/facilities/fac_36.htm

⁴⁹⁰ http://www.wrs.afrl.af.mil/infores/facilities/fac_30.htm

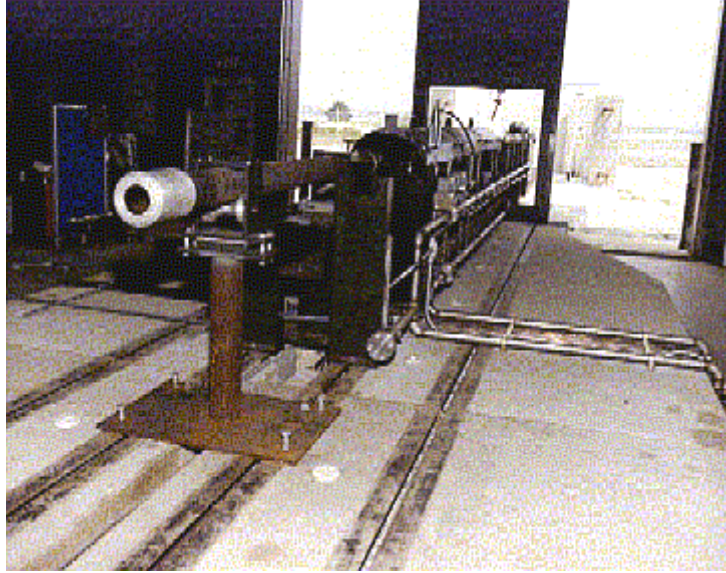


Figure B.12-7 **Electromagnetic Munitions Experimentation Facility Site**

B.12.3 **Instrumentation**

Eglin has the following types of instrumentation that is used in support of tests:

- Radar
- Telemetry
- Optics
- Electro-Optical Time-space-Position
- Communication

Land-based radar and electro-optical time-space-position- information systems are used to monitor the water test areas and to transfer test data to the Central Control Facility on Eglin Main. These instrumentation systems are located at

- Tyndall AFB
- Santa Rosa Island
- Cape San Blas

They provide coverage for test and evaluation activities in the Gulf of Mexico. The land-based systems are supplemented by airborne systems that provide relay links with ground stations. The 46th Test Wing and Aeronautical Systems Center's GPS Range Systems Support Division are currently working on instrumentation pods, which will allow data gathering on test missions anywhere. Also the Test Wing is developing an over-the-water scoring system for bomb, air-to-surface missiles, and aircraft guns⁴⁹¹.

⁴⁹¹ <http://www.globalsecurity.org/military/facility/eglin-range.htm>

Cape San Blas⁴⁹² - The Cape San Blas (Figure B.12-8)⁴⁹³ lighthouse (Figure B.12-9)⁴⁹⁴ area is ideally suited to support Eglin's test mission, particularly as a site for surveillance radar. Projecting into the Gulf, the site provides optimal coverage of missiles, aircraft and aerial targets operating over the Gulf.



Figure B.12-8 Cape San Blas & Lighthouse

Air Force facilities and instrumentation located on Cape San Blas provide a wide variety of mission-support functions. These include flight termination, frequency control and analysis, communications and telemetry, time-space-position information, microwave relay systems, and general mission support.

The Cape is also ideally located for missile and sounding rocket launches. In recent years, Patriot missiles have been tested against aerial targets in the Gulf of Mexico at the site. The site is being considered as a critical component for Theater Missile Defense (TMD) missile system testing as proposed in an Environmental Impact Statement currently being processed by the Ballistic Missile Defense Organization.

The Air Force has also supported rocket launches by the Florida Spaceport Authority at Site D3.

⁴⁹² <http://www.starfl.com/article.cfm?ID=3415>

⁴⁹³ http://dhr.dos.state.fl.us/maritime/lighthouses/light.cfm?name=Cape_San_Blas

⁴⁹⁴ <http://www.ipl.org/div/light/GULF/CapeSanBlas.html>



Figure B.12-9 **Cape San Blas Lighthouse**

B.13 CHINA LAKE

B.13.1 Background

B.13.1.1 General

The Naval Air Warfare Center Weapons Division (NAWCWD) land ranges are located at China Lake, which is situated in the upper Mojave Desert of southern California (Figure B.13-1). The ranges are about 150 miles north of Los Angeles and encompass over 1.1 million acres. China Lake provides an extensive array of land and air ranges, test facilities, and laboratories. The Test and Evaluation (T&E) facilities are located within working proximity of China Lake's Research and Development (R&D) laboratory complexes, allowing military and civilian scientists and engineers to work on total system RDT&E.⁴⁹⁵



Figure B.13-1 Locations of China Lake & Point Mugu Test Facilities

The land⁴⁹⁶ is used exclusively for test and evaluation or as a buffer between sensitive or hazardous tests and the surrounding public lands (Figure B.13-2). Most of the heavily instrumented test facilities are concentrated near the vast dry bed of a pre-historic Pleistocene lake, which covers the southwestern quarter of the China Lake area.

⁴⁹⁵ <http://www.nawcwpns.navy.mil/~pacrange/r1/Land2.htm>

⁴⁹⁶ <http://www.nawcwpns.navy.mil/~pacrange/s1/HeloMap.htm>

The terrain includes:

- Dry flat lakebeds
- Large dry washes
- Alluvial fans
- Open desert
- Pine covered mountains



Figure B.13-2 China Lake Facilities

The weather at China Lake is perfectly suited for testing. There is practically unlimited visibility with very little annual precipitation. Typically, there are 353 flying days per year with unlimited visibility.

The sea range portion of NAWCWD is located at Point Mugu (Figure B.13-3), 65 miles northwest of Los Angeles. An FAA approved low-level route for Cruise Missile testing (IR-200) exists between the Sea Range at Point Mugu and the Land Range at China Lake (Figure B.13-4). Point Mugu is discussed in a separate section.



Figure B.13-3 Point Mugu Navy Test Facilities

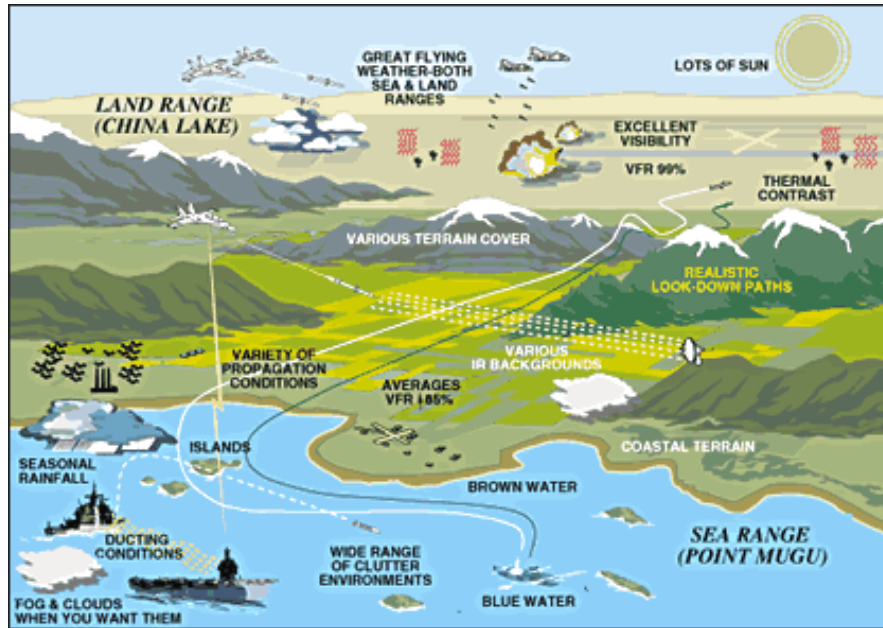


Figure B.13-4 Integrated Activities Between China Lake & Point Mugu

B.13.1.2 History

China Lake was established in 1943 as a facility for test and evaluation of rockets being developed for the Navy by the California Institute of Technology (Cal Tech) and as a new proving ground for all aviation ordnance.⁴⁹⁷ The original name was Naval Ordnance Test Station (NOTS). This first year, Harvey Field was commissioned at the auxiliary landing field at Inyokern. By mid-1945, NOTS' aviation assets were transferred to the new Armitage Field at the China Lake site.

Primary testing and developments at China Lake were with air-launched rockets, solid propellants, fire-control systems, and guided missiles. In the late 1940s, NOTS began research on fire-control systems that evolved into the concept of the Sidewinder air-to-air guided missile. During World War II, the Station played a role in the Manhattan Project as the site of "Project Camel," which developed non-nuclear explosive bomb components -- a role that continued into the 1950s. Holy Moses, Tiny Tim, and a family of spin-stabilized barrage rockets were also fielded-tested around this time. After the War, the Pasadena Annex was added to NOTS, bringing with it the torpedo-development program and other underwater-ordnance RDT&E efforts.

During the Korean conflict, NOTS continued development of rockets, missiles, torpedoes, guns, bombs, and fuses. Rockets included the Ram, Weapon A, Mighty Mouse, BOAR, and Sidewinder. By the late 1950s, research at China Lake had expanded into such diverse fields as weather modification and satellite-delivery systems.

⁴⁹⁷ <http://www.nawcwm.navy.mil/clmf/hist.html>

The Station also played a significant part in developing and testing the Polaris missile system, including performing studies and analyses that shaped the Polaris concept.

During the 1970s, the Center continued to develop missiles like the Sidewinder, Walleye, Shrike, HARM, FAE, Sparrow, Phoenix, Harpoon, and Maverick. China Lake research extended the technology base in optical and laser systems, advanced propulsion technologies, and anti-radiation guidance.

In the 1980s, China Lake assisted in development of the Space Shuttle escape system and the Tomahawk Cruise Missile.

B.13.2 Facilities

B.13.2.1 General

China Lake⁴⁹⁸ contains ranges for testing the following:

- Guided Missiles (George)
- Aircraft Weapon Systems (Baker & Charlie)
- Training & Tactics (Coso)
- Training & Special Operations (Superior valley)
- Mobile Land Targets (Airport Lake)
- Point Defense (G-6)
- Small Missile Range (Redeye Site)
- Randsburg Fuse Range

In addition, China Lake contains the following major facilities:

Range Control Center - The RCC is a centralized range-control facility (Figure B.13-5) that provides test operations control, communication, and coordination.

Airspace Surveillance Center – The ASC is located at the Range Control Center. It provides radar surveillance for China Lake airspace.

High Speed Test Track – China Lake contains two supersonic, dual-rail, heavy-duty research tracks: one four miles long and the other 3,000 feet long. Data may be collected at subsonic or supersonic speeds. The Supersonic Naval Ordnance Research Track (SNORT) is a 4-mile, dual-rail, heavy duty test track capable of handling test vehicles up to 135,000 lbs. and speeds up to 4500 ft/sec (Figures B.13-6 and B.13-7).

⁴⁹⁸ <http://www.nawcwpns.navy.mil/~pacrange/r1/Land4.htm#FACILITIES>



Figure B.13-5 Range Control Center



Figure B.13-6 High Speed Test Track



Figure B.13-7 Ejection Seat Testing

Radar Cross Section (RCS) Range - provides precision RCS measurements of static low observable targets in an isolated outdoor environment.

Explosive Test Ranges - provide capability for static testing of conventional (non-nuclear) warheads and explosive devices.

Bombing Ranges – China Lake contains multiple bombing ranges (Figure B.13-8). Targets include:

- Bridges (Figure B.13-9)
- Radar
- Tunnels
- Truck convoys
- Tanks (Figure B.13-10)
- Surface-to-air missile site



Figure B.13-8 Bombing Targets



Figure B.13-9 Bridge Target



Figure B.13-10

Tank Target

Aerodynamic Heating Facilities - are used to produce aerodynamic heating effects on materials and devices and for low-volume ramjet engine testing

Propulsion Test Ranges - provide the capability for static testing solid- and liquid-propellant rocket motors up to 94 ft. in diameter, 25 ft. in length, and up to 1.5 million lbs. of thrust in variable test attitudes.⁴⁹⁹ This includes:

- **Strategic Systems Propulsion Test Facilities (Skytop)** - Navy's largest and best-instrumented static-firing rocket motor test installation. It is used for testing improved designs for the Trident strategic missile

Naval Air Weapons Station (NAWS) - provides aircraft and airfield facilities as well as air support for RDT&E operations. Facilities include three major runways (one 10,000 ft), 10 types of aircraft, aircraft hangars, maintenance facilities, ordnance handling and storage facilities, and a bore sight range.

Randsburg Fuse Range⁵⁰⁰ - includes two 360-foot-tall wooden towers and a variety of naval guns and surface-launch facilities (Figure B.13-11). Towers can suspend full-scale aircraft targets and shapes 250 feet above the ground, providing fuse test environments that closely simulate tactical conditions.

⁴⁹⁹ <http://www.acq.osd.mil/sts/te/pubfac/china.html>

⁵⁰⁰ <http://www.nawcwpns.navy.mil/~pacrange/r1/Land3.htm#RANGES>



Figure B.13-11

Randsburg Fuse Range

Echo Range⁵⁰¹ - provides highly realistic threat simulation for airborne electronic warfare (EW) equipment/tactics RDT&E and training (Figure B.13-12).

⁵⁰¹ <http://www.nawewd.navy.mil/clmf/echo.html>



Figure B.13-12

Echo Range

B.13.2.2 Launch

Missiles are launched at the Guided Missile (George) and Small Missile Range (Redeye) Sites.⁵⁰²

George⁵⁰³ (Guided Missiles) – This site is used for test and evaluation of air-to-air, air-to-surface and surface-to-air guided missiles. It covers approximately 250 square miles and contains both desert and mountainous terrain. This range is also used as a target area for the cruise missiles launched 150 miles to the southwest.

Small Missile Range (Redeye Site) - Typically supports tests of short-range, surface-to-surface and surface-to-air guided missiles against surface or aerial targets and field evaluations of small tactical air-defense systems. This site shares airspace, downrange area, fixed instrumentation, drone launchers and support facilities with the George Range.

Test activities include potential hazards from developmental ordnance of unproven reliability.

⁵⁰² <http://www.nawcwpns.navy.mil/~pacrange/r1/Land3.htm>

⁵⁰³ <http://www.nawcwpns.navy.mil/~pacrange/r1/Land3.htm#GEORGE>

B.13.3 Instrumentation

China Lake contains the following types of instrumentation:⁵⁰⁴

- Radar
- Global Positioning System (GPS)
- Lidar (light detection and ranging; i.e., light/laser radar)
- Video tracking systems
- Telemetry receiving
- Meteorological data gathering systems
- Fixed and tracking optical cameras
- Real-time data-processing
- Display
- Operations Control

China Lake's most heavily instrumented range is George (Guided Missiles). This range include the following types of instrumentation:

- Video and film-based tracking sites
- Radar
- Portable instrumentation

Radar - Five tracking radars are available:

- 3 X-Bands (3 Nike based OADS)
- 2 C-Bands (1 Nike based OADS, 1 ROTR)

The Nikes are computer calibrated and provide 20-Hz real time and 100-Hz post-test. The ROTR provides 20-Hz real time and 60/120-Hz post-test. Each radar is augmented with video or IR-video (for night operation) cameras.

Telemetry - The Telemetry Receiving Center (T-Pad) receives and records data in real time.

- Receive P, L, and S-band sources up to 20 MHz.
- FM/PCM, PAM, and FM/FM modulation
- Four 6-foot L/S Band antennas at T-Pad
- One P-Band helix antenna system at T-Pad
- One 16-foot and one 6-foot L/S Band antenna system at Laurel Mountain
- One P-Band helix antenna system at Laurel Mountain
- One mobile 8-foot L/S-Band antenna system

⁵⁰⁴ <http://www.nawcwpns.navy.mil/~pacrange/r1/Land5.htm#INSTRUMENT>

- One mobile 6-foot L/S-Band antenna system
- Two mobile P-Band antenna systems
- One 6-foot L/S-Band antenna at Airfield
- 5 IRIG standard Analog Recorders at T-Pad
- Two Mobile 14-track IRIG standard Analog Recorders
- Two Metrum ARMOR/64 digital recorders at T-Pad (20 Mbps/channel, 64 Mbps Aggregate)
- One serial BVLDS digital recorder (32 Mbps)
- One mobile serial BVLDS digital recorder (32 Mbps)
- Enerdyne Video decompression
- Hot mike voice from Telemetry

Optics – There are 20 Kineto Tracking Mount (KTM) instruments (Figure 3.13-13). KTM TSPI data are provided via CCD television cameras. Target tracking is generally human-in-the-loop, but instruments may be remotely slaved to track an externally presented target trajectory/position.

There are also various types of fixed cameras:

- **Metric video:** used to determine the impact point of conventional, guided, and unguided ordnance
- **Bowen cameras:** used in arrays of two or more; obtain highly accurate TSPI in a fixed, small "box"
- **Ribbon frame cameras**



Figure B.13-13

KTM Optical Tracker

GPS - Advanced Range Data System (ARDS) is a GPS-based TSPI system that requires the test participant to carry ARDS software. In the baseline configuration, the hardware is packaged within an airborne pod that aerodynamically simulates the AIM-9 (Sidewinder) missile. The ARDS system provides precision 6-degree-of-freedom TSPI, including position information, pitch, roll, heading, altitude rate, velocity, and acceleration.

Communication - Provides secure and non-secure transmission facilities for all video, voice, and data requirements. It incorporates communications security (COMSEC) and is designed around standard telecommunications hardware, allowing for easy compatibility. It includes fiber-optic distribution facilities, microwave systems, ultra-high frequency (UHF) ground-to-air, VHF ground-to-ground radio systems, digital multiplexing, digital switching, and video.

B.14 HOLLOWMAN

B.14.1 Background

B.14.1.1 General

Holloman AFB is located in New Mexico's Tularosa Basin between the Sacramento and San Andreas mountain ranges (Figure B.14-1). The 59,639-acre base (Figure B.14-2) is about 10 miles west of Alamogordo, New Mexico, on route 70/82. It is 90 miles north of El Paso, Texas, 70 miles east of Las Cruces, New Mexico, adjacent to the White Sands Missile Range. The base supports about 23,000 Active Duty, Guard, Reserve, retirees, DoD civilians and their family members.⁵⁰⁵ It is home to the 49th Fighter Wing and their F-117 stealth fighters. It is also an overseas training site for the German Air Force.



Figure B.14-1 Holloman AFB & White Sands Missile Range

⁵⁰⁵ <http://www.holloman.af.mil/hafb/basedata.html>

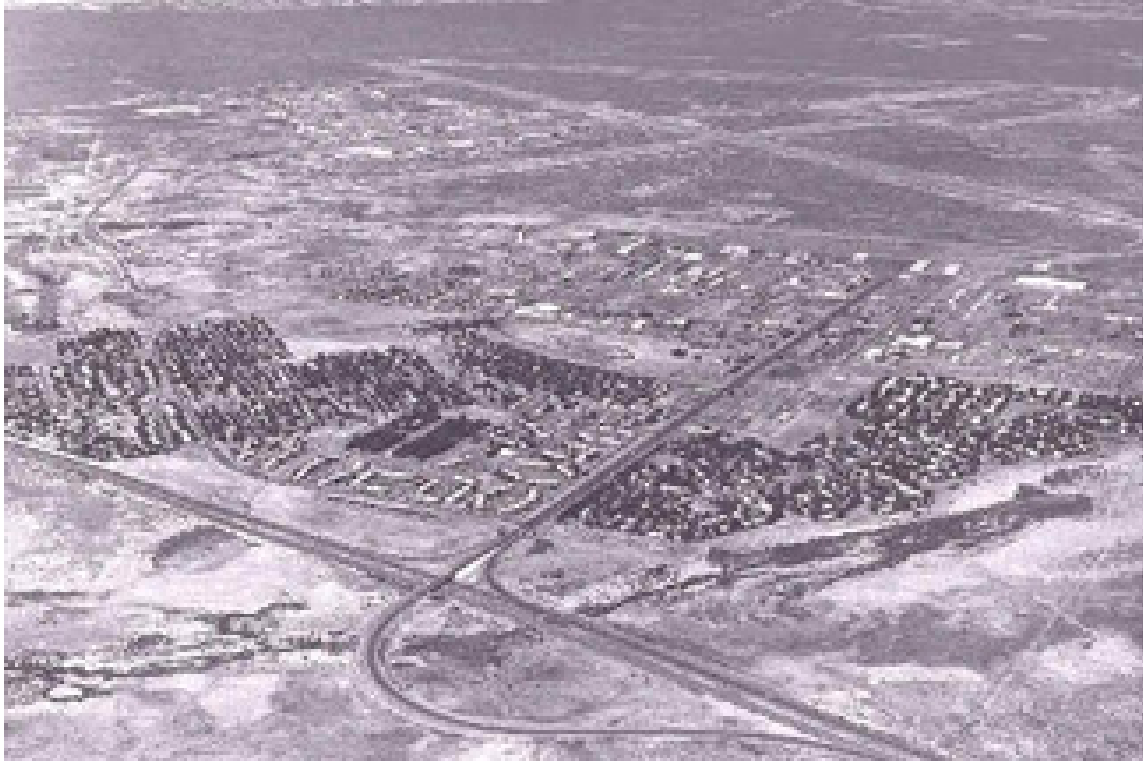


Figure B.14-2 **Holloman AFB**

B.14.1.2 **History**

On June 19, 1942⁵⁰⁶, Alamogordo Army Air Field was established at a site six miles west of Alamogordo, New Mexico. Initially the base was to serve as a British Overseas Training site; however, after the Japanese attacked Pearl Harbor on December 7, 1941, everything changed. The British dropped their plans for overseas training and the U.S. Army took over the site. Construction began on February 6, 1942 and forces began to move in on May 14, 1942. From 1942-1945, Alamogordo Army Air Field served as the training grounds for over 20 different groups, flying primarily B-17s, B-24s, and B-29s.

After World War II, the future of the base was uncertain. In 1947, the Air Materiel Command announced the airfield would be its primary site for the testing and development of pilotless aircraft, guided missiles, and other research programs. For the next 25 years the site, which became known as the Holloman Air Development Center, and later the Air Force Missile Development Center, launched many missiles including Tiny Tim (the first Army rocket), Rascal, V-2, XQ-2 Drone, Falcon, MACE, Matador, and Shrike.

⁵⁰⁶ <http://www.holloman.af.mil/hafb/basehistory.html>

On January 13, 1948 the Alamogordo installation was renamed Holloman Air Force Base, in honor of the late Col. George V. Holloman, a pioneer in guided missile research. In the 1950s and 1960s Holloman Air Force Base was the site of many aerospace “firsts”. On December 10, 1954, Lt. Col. (Dr.) John P. Stapp received the nickname "The Fastest Man Alive" when he rode a rocket-propelled test sled, Sonic Wind No. 1, to a speed of 632 miles per hour. Additionally, Captain Joseph W. Kittinger, Jr. stepped out of an open balloon gondola at 102,800 feet on August 16, 1960, in a successful attempt to evaluate techniques of high altitude bailout. Capt. Kittinger’s jump lasted 13 minutes and reached a velocity of 614 miles per hour. That jump broke four world records: highest open gondola manned balloon flight, highest balloon flight of any kind, highest bailout, and longest free fall. A final noteworthy event occurred on November 29, 1961, when ENOS, a chimpanzee trained at Holloman’s HAM facility (Holloman Aero-Medical laboratory), was the first U.S. specimen launched into orbit. ENOS was launched in a Mercury-Atlas capsule that completed two orbits around the earth and was safely recovered three hours, 21 minutes later.

Aircraft flown at Holloman include: B-17, B-24, B-29, B-57, P-47, AT-38B, F-4D, F-15, F-84, F-100, HH-60G, QF-106, T-38 Talon, F-117 Nighthawk, F-4F Phantom II, QF-4 drone, German Air Force Tornado.

B.14.2 Facilities

Holloman High Speed Test Track - Holloman is home to the world's longest and fastest test track. The Holloman High Speed Test Track (HHSTT) (Figure B.14-3) holds the land speed record at 8,978 feet per second (6,121 miles per hour, Mach 9) (Figure B.14-4).^{507,508} Holloman’s existing dual rail track extends 50,788 feet in a nearly North-South orientation. Currently, test track personnel have a goal of Mach 10 for spring of 2002.⁵⁰⁹ The test track occupies 11 square miles in the northwest area of Holloman AFB and is adjacent to the 4000-square-mile White Sands Missile Range (WSMR). During operations, HHSTT restricts 1000 feet of airspace above the track for safety. Access to the track is limited during preparation and operations. The air space over the area is closed to all civilian air traffic and can be closed to all air traffic when requested.

⁵⁰⁷ <http://www.boeing.com/defense-space/space/maglev/maglevfacts.html>

⁵⁰⁸ <http://www.46tg.af.mil/tests1.htm>

⁵⁰⁹ <http://www.holloman.af.mil/hafb/basedata.html>



Figure B.14-3 **Holloman High Speed Test Track**

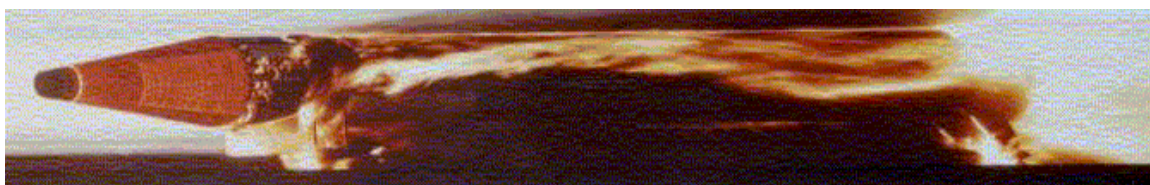


Figure B.14-4 **World Land Speed Record Holder (6121 MPH)**

HHSTT is a one-of-a-kind aerospace ground facility. Test capabilities include the following⁵¹⁰:

- **Aircraft:** crew escape, air blast, bird strike, aero-propulsion, munitions launch, and infrared countermeasures
- **Missile:** guidance systems, aerodynamics, aero-elastics, seekers, components, and dispensers (Figure B.14-5)
- **Life support systems:** crew modules, decelerators, parachutes, canopies, catapults, and ballutes/paraloons

⁵¹⁰ <http://www.acq.osd.mil/te/pubfac/holloman.html#Location>

- **Erosion:** rain, dust/particle, hail, transpiration cooling, material ablation, heat shields, radomes, electro-optical windows, and re-entry phenomena
- **Impact:** warhead, fuse sensitivity, kinetic energy penetrators, hit-to-kill vehicles, hit sensors, survivability/vulnerability, and lethality.

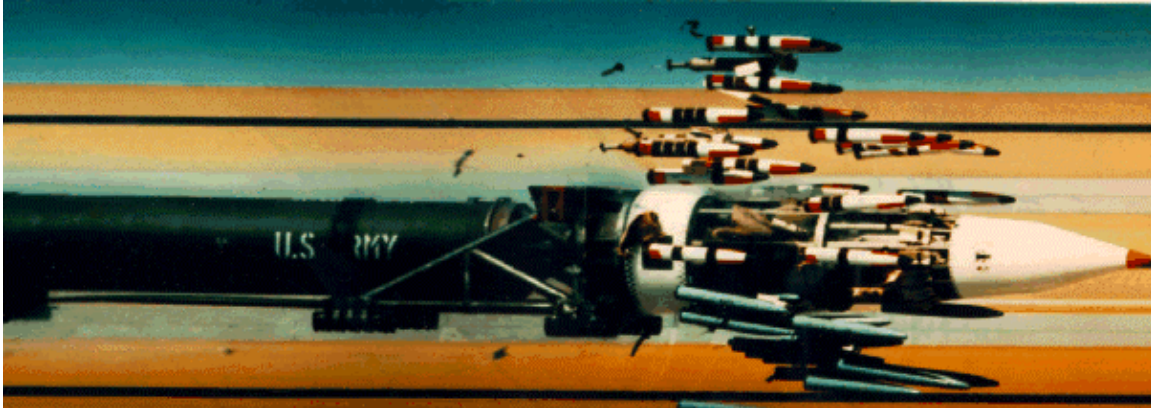


Figure B.14-5 **Dispenser Test**

Experimental missiles have been launched from the Air Launch Sled while on the track under dynamic conditions (Figure B.14-6). Other experimental missile tests have included propulsion, guidance, and homing systems. Similar tests have also included crosswind firings.



Figure B.14-6 **SNARK Missile Launch from HHSTT**

HHSTT is receiving a magnetic levitation upgrade by General Atomics/ Bechtel/Foster-Miller.⁵¹¹ The upgrade is a multi-phased effort to provide a Hypersonic Ground Test Facility for the Air Force and the nation. The MagLev (Figure B.14-7) system will not only provide important test capability for our national defense, but will also establish many of the design parameters needed to understand this technology's potential for launch assist. The purpose of the upgrades is to meet Theater Missile Defense (TMD) lethality testing requirements⁵¹².



Figure B.14-7 Hypersonic Upgrade Test Sled

Key events/dates for the HHSTT are as follows⁵¹³:

- 1949: Construction Began. Original track length - 3,550
- Jun 1950: First sled test
- 1953: First simulated rain field test
- 1954: First track extension to 5,050
- 1954: Dr. John Paul Stapp's sled rides (Mach 0.9 velocity, 40 g deceleration)
- Jan 1955: First inertial guidance test
- 1956: 35,000 foot track extension
- Dec 1957: First impact test off north end of the track
- Mar 1958: First liquid-engine sled test
- Mar 1958: First ICBM test (Minuteman)
- Nov 1962: First escape systems test
- 1964: First hypersonic test
- 1973: Track extended to current length of 50,788 feet
- Oct 1980: First non-nuclear warhead impact test
- Dec 1992: First PAC-3 lethality impact test
- Feb 1994: First Magnetic Levitation Checkout Test
- Jul 1995: First SM-2 Warhead sled test
- Nov 1995: First ejection seat test from the MASE sled
- Apr 1998: First SM-3 Direct Hit sled test
- Aug 1999: First SM-2 Direct Hit Interceptor sled test
- Jul 2000: Test Track 50th Anniversary Celebration

⁵¹¹ <http://www.boeing.com/defense-space/space/maglev/index.html#1>

⁵¹² <http://www.46tg.af.mil/tests1.htm>

⁵¹³ <http://www.46tg.af.mil/history.htm>

- 2002: First 10,000 ft/sec sled test planned

RADAR TARGET SCATTER – The RATSCAT (Figures B.14-8 and B.14-9) is a one-of-a-kind facility combining the best in monostatic and bistatic radar cross-section measurements. It provides precision signature measurements of low observable weapon systems. RATSCAT consists of two separate but complementary test sites. The main site is located on the alkali flats region of White Sands Missile Range. RATSCAT Advanced Measurement System (RAMS) is located 35 miles northwest of the main site at the base of the San Andres Mountains.



Figure B.14-8 Radar Target Scatter Facilities



Figure B.14-9 Radar Target Scatter Range

CENTRAL INERTIAL GUIDANCE TEST FACILITY - The CIGTF complex consists of 10 buildings covering approximately 227,000 square feet. The laboratory operates three centrifuge test beds (Figure B.14-10), with and without counter-rotating platforms, which can subject test items to sustained acceleration environments up to 30g, 50g, and 100g. CIGTF uses a variety of reference systems to provide accurate Time-Space-Position Information in conducting its laboratory, van, sled, and aircraft tests. CIGTF Support Resources include a simulation laboratory, GPS satellite reference station, data analysis stations, and three state-of-the-art Portable Field Jamming Systems.



Figure B.14-10

Centrifuge

B.14.3 Instrumentation

Instrumentation information from Holloman was not readily available in the literature.

C. Theoretical Basis of Railgun Physics

Following and expanding on the method of Paul and Nasar for analyzing the forces on charges due to effects of electric and magnetic fields, the following analysis derives the force equation for railguns based on practical simplifications to the interaction between the magnetic field and the current through the launched-item conductor.⁵¹⁴

Current is the flow of charge versus time. Consider first the force on a test charge Q in the launched item conductor. This force may be computed using the Lorentz force equation. This equation states that the total force exerted on a test charge Q is the sum of the forces due to the electric and magnetic fields, and is given by:

$$\vec{F} = \vec{F}_e + \vec{F}_m = Q(\vec{E} + \vec{u} \times \vec{B}) \quad \text{N} \quad (\text{Eqn. 1})$$

Now, consider a group of charges traveling in an infinitesimally small volume dv in the conductor such that the force density f is uniform within this small volume, and additionally such that there exists a uniform charge density, ρ . The total force is simple the force density times the differential volume. That is,

$$F = f \, dv$$

The charge density ρ is simply:

$$\rho = \frac{Q}{dv}$$

Substituting these into Equation 1, the differential force can be computed as:

$$f \, dv = (\rho\vec{E} + \rho\vec{u} \times \vec{B}) \, dv$$

which means that the differential force is given by:

$$f = \rho(\vec{E} + \vec{u} \times \vec{B}) \quad \text{N/m}^3 \quad (\text{Eqn.2})$$

But, the charge density, ρ , traveling at a velocity \vec{u} is simply the current density \vec{J} such that:

$$\rho\vec{u} = \vec{J}$$

⁵¹⁴ Paul, Clayton R. and Nasar, Syed A., *Introduction to Electromagnetic Fields*, 2nd Edition, McGraw-Hill Book Co. New York, 1982, pp. 187-189.

Equation 2 then becomes:

$$f = \rho \vec{E} + \vec{J} \times \vec{B} \quad \text{N/m}^3 \quad (\text{Eqn. 3})$$

Now, for a perfect, resistance-free conductor, the voltage potential across the rail at the location of the launch item is zero. The Electric Field \vec{E} is therefore zero here, as well. This means that there is no force due to an Electric Field, and all the force is due purely to the current density and the Magnetic Field. For the case of the resistance-free conductor across the rails of the railgun, the differential force becomes

$$f = \vec{J} \times \vec{B} \quad \text{N/m}^3 \quad (\text{Eqn. 4})$$

The current density \vec{J} through the launched conductor is the ratio of the total current \vec{I} divided by the area through which the current flows:

$$\vec{J} = \frac{\vec{I}}{A} \quad (\text{Eqn. 5})$$

Substituting Equation 5 into Equation 4,

$$f = \frac{\vec{I} \times \vec{B}}{A} \quad \text{N/m}^3 \quad (\text{Eqn. 6})$$

Assuming a uniform current, uniform magnetic field, and uniform force through the conductor, and further neglecting any skin effects of high frequency current pulses on the rails, the total force on the launched item becomes:

$$\vec{F}_{total} = \int f \, dv = f \int dv = fV = fAl$$

Substituting this into the previous equation:

$$\vec{F}_{total} = \frac{\vec{I} \times \vec{B}}{A} Al = (\vec{I} \times \vec{B})l \quad \text{N} \quad (\text{Eqn. 7})$$

Or, if only the magnitude of the launching force in Newtons is desired:

$$F = Bli \quad \text{N}$$

where B is the assumed constant magnetic flux existing orthogonal to the rails, l is the length of the conducting bar in meters (i.e., the distance between the two rails), and i is the current in amps passing uniformly through both the rails and the conducting bar between the two rails.

D. Shuttle Landing Sites

D.1 TYPES OF LANDING SITES

The Space Shuttle program is supported by three types of landing sites⁵¹⁵. These are:

- **End of Mission (EOM) Sites**
 - KSC
 - Edwards
 - White Sands

- **Augmented Landing Sites (ALS)**
 - Return to Launch Site (RTLS)
 - Abort-Once Around (AOA)
 - Transoceanic Abort Landing (TAL)
 - Zaragoza Air Base, Spain
 - Moron Air Base, Spain
 - Ben Guerir, Morocco

- **Augmented Emergency Landing Sites (AELS)**

All orbiter landing sites are shown in Figure D.1-1 and summarized in Table D.1-1.

Various types of landing aids are required for EOM sites and ALS. These are summarized in Table D.1-2. ELS require only TACAN/DME.

D.1.1 EOM Sites

EOM sites include KSC, Edwards and White Sands. Prime site is the Shuttle Landing Facility (SLF) at KSC. This was shown in Figure B.2-46. Backup is usually Edwards AFB, California. White Sands, New Mexico has been used once as an EOM with STS-3 in 1982.

D.1.2 Augmented Landing Sites (ALS)

There are three scenarios that fall into the ALS. These are

- ALS Return to Launch Site (RTLS) – The RTLS is the Shuttle Landing Facility (SLF) at KSC.

⁵¹⁵ <http://sspweb.jsc.nasa.gov/webdata/pdcweb/sspdocs/vol10bk3.pdf>

- Abort-Once Around (AOA) – The AOA site is also the SLF at KSC
- Transoceanic Abort Landing (TAL) – TAL sites are available in Spain and Africa. They are
 - Ben Guerir AF, Morocco
 - Moron AB, Spain
 - Zaragoza AB, Spain

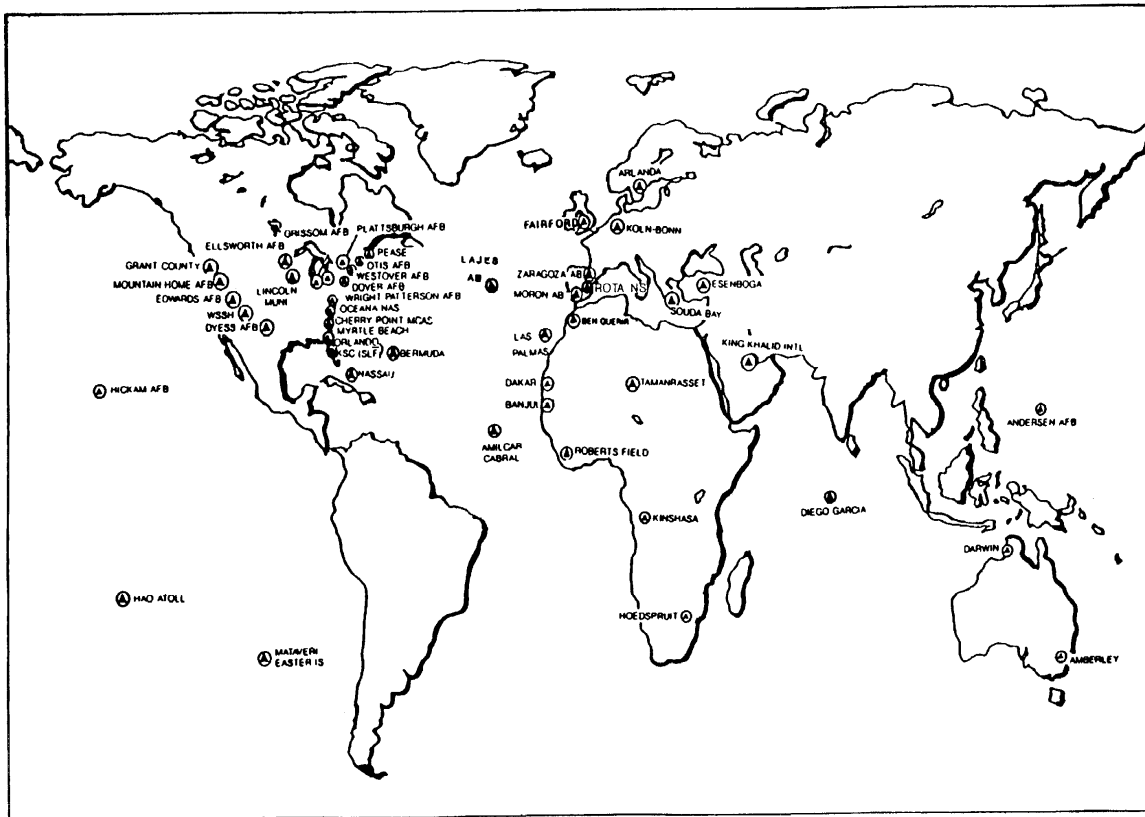


Figure D.1-1 Space Shuttle Landing Sites

Table D.1-1 Space Shuttle Approved Landing Sites

	EOM	RTLS	AOA	TAL	ECAL	ELS LOW	ELS MID	ELS HIGH (50° - 53.5°)	ELS HIGH (53.6° - 63.5°)	REMARKS
Amberley RAAFB, Australia						X	X	X	X	
Amilcar Cabral International, Cape Verde						X	X			
Andersen AFB, Guam, USA						X	X	X	X	
Arlanda, Sweden									O	Above 57°
Ascension AUX AF, Ascension Island, UK								X	X	
Atlantic City International, Atlantic City, NJ, USA					X			X	X	
Banjul International, The Gambia						X	X			
Beja, Portugal								X	X	
Ben Guerir AB, Morocco				X		X	X	X	X	
Bermuda International, St. David's Island, Bermuda						X	X			
Cherry Point MCAS, NC, USA					X			X	X	
Diego Garcia NSF, Chagos Archipelago, U.K.						X	X	X	X	
Dover AFB, Delaware, USA					X				X	
Dyess AFB, Texas, USA						X	X	X	X	NOR AOA Weather (WX) Alternate
Edwards AFB, CA, USA	X		X			X	X	X	X	
Ellsworth AFB, SD, USA								O	O	
Elmendorf AFB, Anchorage Alaska, USA								X	X	
Esenboga, Turkey								X	X	
Fairford RAF, England								X	X	Ascent Only
Gander International, Newfoundland, Canada					X			X	X	
Goose Bay, Newfoundland, Canada					X				X	
Gran Canaria, Las Palmas, Canary Islands, Spain						X	X			
Grant County, WA, USA								O	O	
Halifax International, Nova Scotia, Canada					X			X	X	
Hao Atoll, Tuamotu Arch., Fr, Polynesia, France						X	X	X	X	
Hoedspruit AFS, South Africa						X	X			
Honolulu International, HI, USA						X	X	X	X	
King Khalid International, Riyadh, Saudi Arabia						X	X	X	X	
Kinshasa/N'Djili International, Zaire						X				
Koln-Bonn, Germany								X	X	
KSC (SLF), FL, USA	X	X	X			X	X	X	X	
Lajes AB, Azores, Portugal								X	X	Approved High & Mid Incln. Only
Le Tube, Istres, France								X	X	Ascent Only
Lincoln Municipal, NE, USA								O	O	
L.S. Senghor International, Dakar, Senegal						X				No Agreement for Use
Monrovia/Roberts International, Liberia						X	X			
Moron AB, Spain				X		X	X	X	X	
Mountain Home AFB, ID, USA								O	O	

Table D.1-1 (Continued)
Space Shuttle Approved Landing Sites

	EOM	RTLS	AOA	TAL	ECAL	ELS LOW	ELS MID	ELS HIGH (50° - 53.5°)	ELS HIGH (53.6° - 63.5°)	REMARKS
Myrtle Beach, SC, USA					X				X	
Nassau International, New Providence Island, Bahamas						X	X	O	O	Underburn in Software
Northrup (WSSH), NM, USA	X		X			X	X	X	X	
Oceana NAS, Virginia Beach, VA, USA					X			X	X	
Orlando International, FL, USA						X	X	O	O	Underburn in Low Software
Otis ANGB, MA, USA					X			X	X	
Pease International Tradeport, Portsmouth, NH, USA					X			X	X	
Piloto Civil Norberto Fernandez, Rio Gallegos, Argentina								X	X	Government Approval Pending
St. Johns International, NF, Canada					X			X	X	
Shannon, Ireland								X	X	Ascent Only
Souda, Chania, Greece						X	X			Above 40° Inclination Only
Stephenville, Newfoundland, Canada					X			X	X	Prior Coordination for Night Use
Tamanrasset, Algeria							X			Mid Inclination Ascent Only
The Francis S. Gabreski, Westhampton Beach, NY, USA					X			X	X	
Tindal RAAF, Australia						X	X	X	X	
Wake Island AAF, Wake Is., USA								X	X	
Wallops Flight Facility, Wallops Island, VA, USA					X			X	X	
Wilmington International, Wilmington, NC, USA					X			X	X	
Yokota, Tokyo, Honshu Is., Japan								X	X	
Zaragoza AB, Spain				X			X	X	X	

Sites not currently being used on the Landing Site Tables

ELS LOW - Emergency Landing Sites available for low inclination KSC launches
ELS MID - Emergency Landing Sites available for mid inclination KSC launches
ELS HIGH - Emergency Landing Sites available for high inclination KSC launches
O - Downrange abort or deorbit underburn sites; coordinates not carried in onboard software

D.1.3 Emergency Landing Sites

ELS are located all over the world and throughout the U. S. These were previously listed in Figure D.1-1 and Table D.1-1

Table D.1-2 Landing Site Support Requirements

	TACAN/ DME	MLS-JR MSBLS	AIM POINT	PAPI LITES	BALL- BAR	RWY LITES	DIST TO GO MKR	NITE XENON	UHF COMM	UHF AIR	WX AIR- CRAFT	CONVOY	RESCUE	MEDICAL	FIRE/ CRASH	INMARSAT
EOM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
RTLS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
AOA	X	X	X	X	X	X	X	X	X	X		X	X	X	X	
TAL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ELS	X															

EOM - End of Mission Site

RTLS - Return to Launch Site

AOA - Abort-Once-Around Site

TAL - Transoceanic Abort Landing Site

ELS - Emergency Landing Site

INMARSAT - International Maritime Satellite

Fullup Convoy - Provides for Orbiter purge within 45 minutes of landing and no power interruption from landing through turnaround operations. Normally present at planned EOM day only at planned EOM site.

Mini Convoy - Provides for Orbiter purge within eight hours of landing. No electrical power is available during towing operations. The configuration normally supports AOA and prime landing site landing opportunities during orbital operations. (BOTH CONVOYS SUPPORT CREW EGRESS AND ORBITER TOWING TO A SAFE SITE.)

D.2 LANDING SITE EQUIPMENT REQUIREMENTS

The following equipment and services augment EOF and TAL sites:

- **Navigation Aids**
 - TACAN
 - MSBLS
- **Visual Aids**
 - Ball-Bar Lights
 - Precision Approach Path Indicator (PAPI) lights
 - Distance-to-Go Markers
 - Xenon Lights (Night operations)
 - Runway Lighting
 - Approach Lighting
 - Threshold Lights
- **Communications**
 - Commercial.
 - Air-to-Ground
 - FM Portable Radios
 - INMARSAT
- **Transportation**

- **Security**
- **Fire, Crash & Rescue**
- **Meteorology**
- **Medical**

D.3 EQUIPMENT / SERVICES DESCRIPTIONS

Equipment and services identified above and in Table D.1-1 are described below in the following sections.

D.3.1 TACAN

This is military omnibearing and distance measuring equipment (DME) system. Standard requirements for the military TACAN are 1.0 degrees and <.5 nm accuracy. NASA controlled TACANs are <1.0 degree and <.1 nm accuracy.

D.3.2 Microwave Scanning Beam Landing System (MSBLS)

There are two styles of microwave scanning beam landing systems

D.3.2.1 Microwave Scan. Beam Lndg Sys – Gnd Stat (MSBLS-GS)

The MSBLS-GS provides Azimuth (Az), elevation (El), and distance (DME) information to the Orbiter as it approaches the landing site. The equipment is housed in two shelters with one used for Az and DME and the other used for El. Redundant equipment is provided for each. MSBLS are located 300 to 500 feet left or right of the runway centerline.

D.3.2.2 Microwave Scanning Beam Landing Sys – Jr (MSBLS-JR)

The MSBLS-JR is a derivative of the MSBLS-GS system without the redundancy and with all equipment combined in one shelter. The JR was intended as an approach aid for use at the TAL and AELS.

D.3.3 Aim Point

The visual aim point is a triangle (110 feet x 240 feet) located at the high wind aim point.

D.3.4 PAPI Lights – OGS

Precision Approach Path Indicator lights are used to assist the crew on the Outer Glide Slope (OGS). The system contains a set of four lights that convey to the pilot if his approach angle is correct (20 degrees). Two of the lights are white and two are red. When the Orbiter is on the correct approach angle, the pilot sees two reds and two whites. When high of the ideal glide path, the pilot sees 3 whites and 1 red or 4 whites. When low of the ideal glide slope, the pilot sees 1 white and 3 reds or 4 reds.

D.3.5 Ball-Bar Lights – IGS

The ball-bar light system provides the Orbiter pilot a visual means of attaining and maintaining the proper Inner Glide Slope (IGS) angle during Shuttle landing operations. The geometry of the height and spacing of the ball-bar is such that when the white ball lights are superimposed on the red bar lights, they will exhibit a 1-1/2 degree IGS as viewed by the flight crew during their approach. If the energy managed glide slope is maintained, the ball lights will appear to move from the inner bar light to the left, superimposing the white ball lights on each set of red bar lights consecutively as the Orbiter nears touchdown.

D.3.6 Runway Lights

Three types of runway lighting are specified.

D.3.6.1 Edge Lights

Existing runway edge lighting are used. Special edge marking reflectors are used on the MSBLS equipped lakebed runways.

D.3.6.2 Approach Lights

Existing FAA, military or International Civil Aviation Organization approach lighting is acceptable for night landings.

D.3.6.3 Threshold Lights

This lighting system is to identify the runway threshold. These are used for both day and night operations.

D.3.7 Xenon Lights

Xenon lights are used to illuminate the touchdown and rollout areas for night landings.

D.3.8 Runway Distance Remaining Markers

These markers are used to provide runway distance remaining information to flight crews during landing operations. The marker inscriptions consist of a number denoting the distance, in thousand of feet, of the runway remaining to the end of the Shuttle runway.

D.3.9 Communications

There are four communication systems required to landing sites.

D.3.9.1 Commercial

Commercial lines are used as a backup to the international Maritime Satellite (INMARSAT) to maintain contact between KSC and TAL sites from one hour prior to launch until a successful orbit is announced.

D.3.9.2 Air-to-Ground

Air-to-ground systems are used to communicate with weather aircraft and Orbiter.

D.3.9.3 FM Portable Radios

FM portable radios are used to support ground operations during pre-launch and launch activities.

D.3.9.4 INMARSAT

Primary TAL sites have these terminals available for use, prior to and after launch, with KSC and JSC used to maintain contact with the TAL sites from L-1 hour through main engine cut-off.

D.3.10 Transportation

Pre-arranged requirements and transportation are made with all approved landing sites.

D.3.11 Security

Prearranged security is available at all approved landing sites and the launch site

D.3.12 Fire, Crash & Rescue

Trained crews are available where noted to control emergency situations in fire, crash and rescue.

D.3.13 Meteorology

Weather systems provide a constant update of meteorological conditions at specific landing sites.

D.3.14 Medical

Trained specialists provide medical assistance to Orbiter crews during emergency situations.

RISM – Phase 1

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