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## Paper Session I-A - Titan IV Integrate. Test and Launch Facility System Improvements

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*Titan IV Integrate, Test and Launch  
Facility System Improvements*

29th SPACE CONGRESS  
DoD Space Operations

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I. INTRODUCTION:

In order to sustain our quest for new frontiers, we must first appreciate how we attained our present accomplishments. We are transitioning from the research and development phase into the operational phase of accessing space. Three decades ago we struggled with the idea of placing a basketball sized satellite into space and today the Titan IV system is installing school bus size payloads in Earth orbit and beyond. The scope of this paper is to briefly describe the Titan IV system, including the flight hardware, facilities and ground equipment, and explain how this system is improving at the Eastern Launch Site (ELS) to assure reliable, cost effective access to space for the Department of Defense (DoD) larger payloads.

II. BACKGROUND:

The Titan rocket, from its inception in the late 1950's to the present, has become the workhorse for the United States Air Force (USAF). The Titan and its associated infrastructure is a constantly evolving system which continues to meet the needs of the nation. The capability to anticipate and adapt to new environments and requirements has made the Titan the most powerful and versatile expendable rocket in the United States fleet achieving a mission success rate of 96% over three (3) decades.

Table II-1 summarizes the life span of the Titan configurations depicted in Figure II-1, from 1959 when it was being developed as an ICBM for national security, through the 1960's and 1970's when it was NASA's choice for the Gemini and Viking planetary missions, to the present as the Titan IV is responsible for placing the DoD's largest payloads into orbit. This summary illustrates the dynamic nature of vehicle configurations and their varied uses. A new configuration, as an average, was introduced approximately every 3 to 4 years.

VEHICLE	LAUNCH DATE	EVENT
TITAN I	06 FEB 1959	ICBM TESTING
TITAN II	16 MAR 1962	ICBM SILO TEST
TITAN III A	01 SEP 1964	FIRST LAUNCH
TITAN II	23 MAR 1965	GEMINI MANNED FLIGHT
TITAN II	11 NOV 1966	LAST LAUNCH
TITAN III E	11 FEB 1974	PLANETARY MISSIONS
TITAN III C	06 MAR 1982	LAST LAUNCH
TITAN 34D	22 OCT 1982	FIRST LAUNCH
TITAN 34D	04 SEP 1989	LAST LAUNCH
TITAN IV	14 JUN 1989	FIRST LAUNCH

TABLE II-1 - TITAN CONFIGURATIONS

To step smartly into the new frontiers will require a versatile, robust, flexible and reliable launch system which includes flight hardware, facilities, equipment and processing teams.

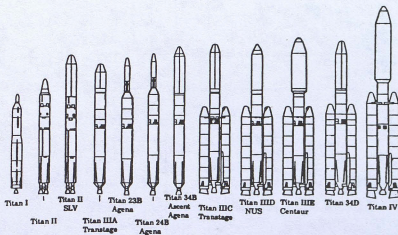


FIGURE II-1 - THE TITAN FAMILY OF SPACE LAUNCH VEHICLES

### III. TITAN IV FLIGHT HARDWARE:

The Titan IV vehicle characteristics are illustrated in Figure III-1. To accommodate the myriad of payloads and provide system robustness desired by the USAF and the payload community, Martin Marietta has a product development team in place to satisfy today's needs and tomorrow's quest. Figure III-2 shows the major elements comprising the Titan IV and the team members responsible for providing this hardware.

PAYLOAD FAIRING LENGTHS	66 - 86'		56'		66'		56 - 86'	
UPPER STAGE	CENTAUR		INERTIAL UPPER STG		NO UPPER STAGE		NO UPPER STAGE	
MISSIONS	GEOSYNCHRONOUS ORBIT		GEOSYNCHRONOUS ORBIT		100X100nmi INC 90°		LOW EARTH ORBIT	
	SRM	10,000#			SRM	32,160#	SRM	38,784#
	SRMU	13,500#	SRMU	5,000	SRMU	41,400#	SRMU	50,000#

FIGURE III-1 TITAN IV CONFIGURATION

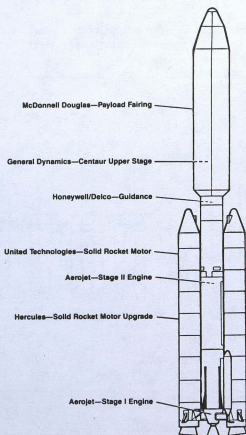


FIGURE III-2 TITAN IV TEAM MAKEUP



The Chemical Systems Division (CSD) Stage 0 Solid Rocket Motors (SRM's) have successfully lifted all Titan IV missions to this date off the launch complexes. Figure III-3 identifies the major components of the SRM configuration used today. CSD is continuing to improve performance and ultimately provide increased weight to orbit. These improvements include using a taller SRM (i.e. additional segments) as well as auxiliary Algol strap-on rockets.

Hercules is presently developing and testing a graphite epoxy filament wound Solid Rocket Motor Upgrade (SRMU) to provide approximately 25-35% more payload to orbit. Table III-1 compares the physical properties of the two Stage 0 configurations scheduled to fly.

	WEIGHT (LBS)	DIAM (FEET)	LENGTH (FEET)	# OF SEGMENTS	CASING TYPE
SRM	697,000	10	112	7	STEEL
SRMU	770,000	10.5	112	3	COMPOSITE

TABLE III-1 - STAGE 0 PHYSICAL PROPERTIES

A study is in progress to determine if additional hardware, including a liquid propelled Stage 0, may be a useful alternative in the coming years.

The Martin Marietta developed Stage 1 and Stage 2 are used solely for propulsion purposes and are powered by Aerojet engines supplied with hypergolic liquid propellants. Each stage has a fuel and oxidizer tank. Table III-2 provides configuration and performance data for each stage.

	# of Aerojet Engines	Aerozine 50 Fuel	Nitrogen Tetroxide Oxidizer	Expansion Ratio	Thrust	Flow Rate
STAGE 1	2	117,000 #	22,000 #	15:1	530,000 #	1780 #/sec
STAGE 2	1	27,000 #	49,000 #	49:1	100,000 #	325 #/sec

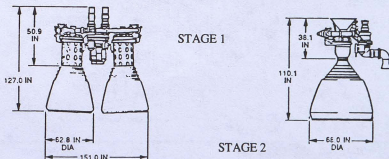


TABLE III-2 STAGE 1 & 2 CONFIGURATION/PERFORMANCE DATA

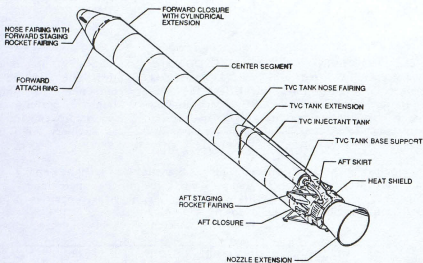
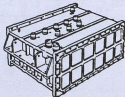


FIGURE III-3 TITAN SOLID ROCKET MOTOR

The Titan IV guidance system presently provided by Delco is critical to the success of the flight. It determines the position and velocity and is responsible for directing the launch vehicle to a pre-determined location in space for separation of the upper stage or spacecraft. The Delco system has two (2) main components shown in Figure III-4 which provide the data to control the vehicle. A new guidance system, developed by Honeywell, is scheduled to fly in the near future. This new system will improve the Titan robustness as well as increase capability as it is approximately half the weight, has reduced power requirements, has an increased memory (approximately 5 fold) and is an order of magnitude faster. To improve the operational aspects, the unit is one self-contained box with a strap down design, fewer parts equating to less mechanical complexity.

Delco (Guidance)

MISSILE GUIDANCE COMPUTER (MGC)



INERTIAL MEASUREMENT UNIT (IMU)

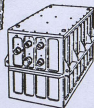


FIGURE III-4 GUIDANCE AND CONTROL

The Titan IV payload fairing configurations are produced by McDonnell Douglas. The fairings are assembled to the required length to accommodate the different size payloads and upper stages including larger by volume than Shuttle class payloads (reference Figure III-5). The payload height is varied in 10' increments between 56 feet and 86 feet. In-flight, the fairing separates into 3 sectors and exposes the payload.

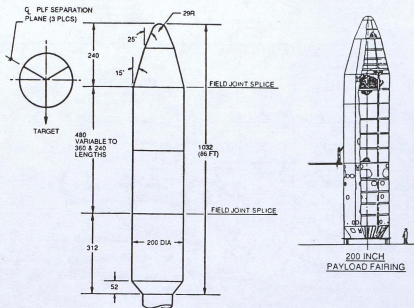


FIGURE III-5 TITAN IV PAYLOAD FAIRING

The Titan IV system primarily uses the Inertial Upper Stage (IUS) (reference Figure III-6) built and processed by Boeing when a solid propellant upper stage is required and the Centaur (reference Figure III-7), built and processed by General Dynamics, is utilized when a restartable liquid propellant upper stage is more advantageous to meeting mission requirements. In addition, the Titan IV system is capable of integrating and delivering to orbit, spacecraft with no upper stage required or an auxiliary propulsion system integrated into the spacecraft.

New spacecraft are being developed, new materials are being discovered, new technological improvements are emerging, proving that change is inevitable. The Titan IV, with its mix and match versatility, provides the flexibility and robustness necessary to meet the nation's needs now and in the future. The fact that we recognize, that change is inevitable, and we are prepared to manage that change under the direction of the USAF, is the key to continuing to provide a reliable delivery system to space and new frontiers.

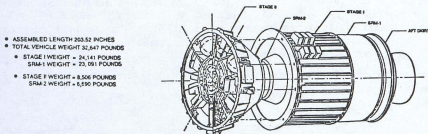


FIGURE III-6 TWO STAGE IUS CONFIGURATION

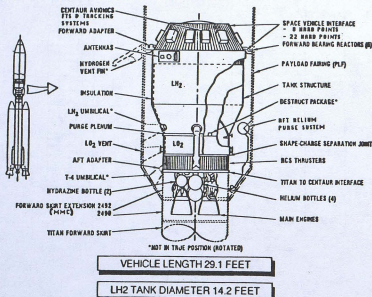


FIGURE III-7 CENTAUR VEHICLE CONFIGURATION

#### IV. PROCESSING FACILITIES & EQUIPMENT

An important factor to consider in a reliable delivery system, such as the Titan IV, are the facilities and equipment necessary to process and launch the flight components. To preserve the flexibility and robustness of the Titan IV total system, the facilities and equipment must be versatile enough to support the present launch vehicle configurations and new ones under development as well as withstand the environmental conditions, including those produced from launching, weather and age.

The Titan IV Integrate, Test and Launch (ITL) facility is located at Cape Canaveral Air Force Station (CCAFS) (reference Figure IV-1), and is an exemplary facility. The ITL facility design provides for multiple vehicle processing in parallel. The initial design has withstood the test of time. Modifications to existing structures and additional facilities have been constructed to accommodate the changing requirements.



FACILITY	MODIFICATIONS	REASON
VIB Core Processing Cells	<ul style="list-style-type: none"> <li>• Additional access platforms</li> <li>• Modification to existing platform diameters</li> <li>• Modification to vehicle support structure</li> </ul>	Larger payload requires taller, wider & heavier vehicles
VIB Cell 3	<ul style="list-style-type: none"> <li>• Modified into a Centaur Processing and storage area</li> </ul>	Centaur capability added Titan robustness
Payload Fairing Annex and Cleaning Facility	<ul style="list-style-type: none"> <li>• Additional Area to process &amp; clean fairings</li> </ul>	Multiple config's and larger payload fairings up to 86' added flexibility
SMAB/SMARF	<ul style="list-style-type: none"> <li>• Solid Motor Assembly &amp; Retest Facility constructed</li> </ul>	<ul style="list-style-type: none"> <li>• Supports processing of taller &amp; heavier solids</li> <li>• Improves schedule for SMAB, IUS &amp; SPIF processing</li> </ul>
LC-41	<ul style="list-style-type: none"> <li>• Refurbishment of existing systems, including activating Centaur processing and cryogenic loading systems</li> </ul>	To provide capability to launch Titan IV's yet maintain a capability to launch 34D and Commercial Titans.
LC-40 (1)	<ul style="list-style-type: none"> <li>• Dismantle existing umbilical tower &amp; mobile service tower to ground level and rebuild</li> </ul>	To accommodate TIV configurations and improve processing operations to support the launch rate
Launch Operations Control Center (LOCC)	<ul style="list-style-type: none"> <li>• Construct and outfit a new control center with improved communication (fiber optics) and data processing</li> </ul>	Accommodate increased data processing for multiple configurations and moves toward a universal launch control center to accommodate future changes.
Centaur Processing Facility (1) (CPF)	<ul style="list-style-type: none"> <li>• Construct a new Centaur Processing Facility</li> </ul>	<ul style="list-style-type: none"> <li>• Compliments VIB Cell 3 to accommodate launch rate.</li> <li>• Allows off pad processing of Centaur including cryogenic loading.</li> </ul>

(1) Not presently complete

TABLE IV-1 ITL FACILITY MAJOR MODIFICATIONS



Table IV-1 illustrates some of the ITL facilities and major types of modifications completed or in progress to support the Titan IV and a brief synopsis of what necessitated that change. In managing these changes the Titan Team is improving the process from anticipating the new requirements and proactively organizing product teams and establishing partnering arrangements to assure fast, cost effective completion of the improvements. In addition to integrating the latest technologies, materials and decades of experience and lessons learned into the design, the projects are managed by the people that will operate the facility which assures consideration of life cycle cost.

The benefits associated with this approach and style are becoming evident. A comparison between refurbishing Launch Complex 41 and rebuilding of Launch Complex 40 illustrates some of the benefits. At the start of the LC-41 refurbishment design effort the Titan IV was to be a Complimentary Expendable Launch Vehicle with approximately 2 launches per year for 5 years. Operational enhancements and expensive refurbishment was not necessary for a short life program. However, after the Challenger accident and the off-loading of payloads from the National Space Transportation System (STS) the role of the Titan IV Expendable Launch Vehicle (ELV) expanded. Some manifests showed up to 8 launches/year from the CCAFS which would require emphasizing operational enhancements, longevity, robustness and flexibility.

The differences between LC-41 and LC-40 illustrate how anticipating change and designing versatility into todays facilities will better support tomorrows needs.

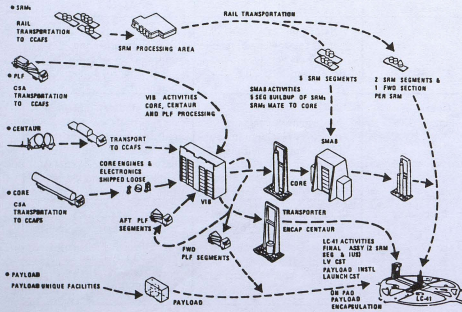


FIGURE IV-1 TITAN CENTAUR FLOW DIAGRAM - ITL FACILITY

The demolishing and raising of LC-40 opposed to the patch-up and rework on LC-41 has numerous advantages. LC-40's new Mobile Service Tower (MST) and Umbilical Tower (UT) has improved flexibility and robustness in the following areas when compared to LC-41:

- Provides a Payload Fairing Staging Area which allows for in-line payload fairing processing at the pad & improves processing timelines.
- Improved EMI attenuation with present state-of-the-art devices on all circuitry and entry points.
- Improved environmental conditioning system scarred to service additional payload areas.
- Communication system has four (4) times as many devices as LC-41 to support increased data requirements.
- Oxidizer scrubbers and fuel incinerators installed to assure all vapors expelled are compliant with Department of Environmental Regulation Standards.
- Access platforms are of the aperture design minimizing personnel effort and maximizing access as well as accommodating future changes.
- Reliability, supportability, maintainability teams evaluated all critical systems during the design phase and levied requirements and specifications to be built in.

These improvements, even with today's materials and construction methods, more than doubled the weight of the Mobile Service Tower from 2600 tons on LC-41 to 6500 tons on LC-40. However, the project will be completed to support launch of Mars Observer in half the time (i.e. 2.5 years vs. 5 years for LC-41). The Mars Observer mission is scheduled in the fall of 1992 and the launch complex will be ready for use in July.

We expect to improve these results even further as Integrated Product Development Teams mature, concurrent engineering processes are fully implemented, and partnering becomes standard operating procedure.

The tangible cost savings with this approach is not easily quantified this early in the process especially when life cycle cost, impacts to operations or cost avoidance measures are considered.

Another new improvement to the ITL is the Solid Motor Assembly and Retest Facility (SMARF) which is undergoing final outfitting and validations for first use, which is scheduled in April 1992. This facility will be used to process the CSD SRM's as well as the newly designed Hercules SRMU's. This facility is new from the ground up and will improve operational timelines as the Stage 0 can be fully assembled prior to transport to the pad. In addition, the facility has provided for additional flexibility by providing support stands to allow the Stage 0 configurations to be more easily mixed or matched to support mission requirements and changes in manifests. The design anticipated the operational needs and proactively sought solutions in the early phases of the project.

The following are some of the highlights associated with the SMARF project:

- Design and construction were finished ahead of schedule.
- Cost was within budget.
- Modifications/corrections were below average as compared to similar projects
- Users of the facility are satisfied with the product and anxious to use it.

The partnering and team approach will continue to be used through the final outfitting of the ground equipment used for checkout and testing of the flight hardware. Similar results are expected in this phase.

Although LC-40 and the SMARF are two examples of starting over at ground level, improving on existing systems is often the preferred option. The Titan IV is transported around the ITL on railcars. The ITL rail system improved its load carrying capability to support the increased weight of the new configurations. This task required a reinforcing plate be installed on the 8 miles of ITL rails using approximately 35,000 bolts which needed to be drilled and secured into concrete. The labor and resulting cost was significantly reduced when CCAFS design team members recommended changing the design and utilizing enhanced materials previously proven in the field.

Another method of improving our operational capability is using equipment utilized on previous programs. One example of this uses the power supplies that became available as a result of the Titan II site-deactivation. These units are being used on LC-40 and LC-41 to power the Propellant Transfer and Pressurization Systems as a dedicated power source.

The down-time associated with the lack of dedicated power was estimated at 1600+ manhours per launch. The tangible cost savings in this case is \$31,000+ per launch. The intangibles, such as operational convenience and improved launch schedules, provide increased assurance to the users that access to space is routine.

The ground equipment used to checkout, test and launch the Titan IV is being developed concurrent with changes in the vehicle. The Programmable Aerospace Ground Equipment (PAGE) is arriving and is presently being installed. The key, again, is "change is inevitable" and the programmable capability will aid the process. PAGE replaces current Titan IV Aerospace Ground Equipment which, due to its age, is difficult to maintain and does not have the capability, as currently designed, to monitor, checkout, and launch the Titan IV improved launch vehicles. The PAGE segment replaces the following existing launch support equipment at CCAFS.

- Launch Control Console (LCC)
- Programmable Aerospace Control Equipment (PACE)
  - Replaces Launch Control Assembly (LCA)
  - Replaces Vehicle Control Assembly (VCA)
- Guidance Control Monitor Group (GCMG) - II
- Tracking and Flight Safety Monitor Group (TFSMG)
- Flight Safety Checkout Control Monitor Group (FSCCMG)
- Van Power Distribution and Control (VPDC)



- Data Transmission Set (DTS)
- Data Communication Equipment (DCE)
- Control Center Power Distribution Control (CCPDC)
- Pulse Tracking Control Monitor Group (PTCMG)
- Telemetry Data Processing Set (TDPS) and GIE
- Launch Pad Power Distribution Control (LPPDC)
- PACE Emergency Shutdown Circuitry

PAGE also provides for on-line storage of test data for many vehicles which before had to be recalled from magnetic tape. The on-line storage plus new workstations provide capabilities for greatly enhanced analysis of specific test and trend data. The increased computing power of PAGE allows for greater automation of the Receipt-to-Launch (RTL) cycle such that PAGE not only runs the Boost Vehicle Combined System Test/Integrated System Test (CST/IST), Launch CST and Launch Countdown, but automates subsystem testing as well. Where operators had to watch strip charts, lights, alarms and gages on the old system, PAGE provides automated monitoring and fault detection/fault isolation such that only a few operator positions are needed. PAGE also provides for automated development and checkout of the automated test sequences used to stimulate and monitor responses of the launch vehicle (LV). Lastly, PAGE provides a simulation function primarily for the purpose of test sequence development and checkout, and secondarily for assistance in post test support. The system is of modular design to minimize impacts of hardware or software upgrades. A Universal PAGE System is also being explored at this time.

#### V. CONCLUSION:

These changes and improvements in flight hardware and facilities were no accident, nor did they happen by chance. Changes in world politics, the state of the US economy and the global marketplace required the government and its contractors to improve their processes and products. The U.S. Air Force, Martin Marietta, and their associated subcontractors, set a course to empower all levels of the work force to improve the system. The examples discussed earlier are a result of this empowerment and the environment, created by management, promoting continued process improvement.

Adolescence is defined as a period of rapid change. Access to space is in its adolescence phase. The USAF recognized this at the onset of the Titan IV program when it chose Martin Marietta to provide overall systems engineering and integration, payload integration and launch services as well as build the first & second stages for the program. New processes and tools had to be developed to manage these changes. Partnering, concurrent engineering, and High Performance Work Teams (HPWTs) are all part of the process in achieving Total Quality Management (TQM) and are now functioning as part of the Titan IV system. Our vision, to be the recognized world class provider of launch services was strengthened as top management demonstrated their commitment and support of the High Performance Work Teams (HPWT's).

After completing the company wide introductory training, teams were provided tools and training which included the Shuehart Cycle (Plan-Do-Check-Act), Pareto Analysis, Brainstorming, and Flow Charting. Team membership had to include all areas affecting the process and product

including the customer, the provider and the supporting organizations. These team members fingered into their home organizations to assure total involvement and support of the critical process improvements identified.

The journey to continuous process improvement is never ending, however in 1991, the Titan Team celebrated process improvements in: Request for Information (RFI)/Liasion Call (Licall) system, travel authorizations, Battery Load Test, Vehicle Electrical checkout test, Cables for Combined Systems Tests (CST), lightning protection, signature process for non-conformance paperwork (MARS), Command Media review, engine shelf life, Principal Inspector, Facility Change/Work Requests and quality work life. In May 1991, the Administrative, Automated Test Tool, and Tracking & Flight Safety teams were recognized and rewarded as Top Performers for exceptional process improvements from Martin Marietta Space Launch Systems. These successes propelled us into 1992 and proved we had another viable system in place to manage change as we methodically approach the future.

In addition to the flight hardware facilities, equipment and process changes being managed, it was obvious organizational changes were necessary to support them. Organizational changes emphasizing operations have been implemented and will continue to be evaluated for improvements. Cross training of personnel has been initiated, utilizing operations personnel in activating and validating new facilities and modifications is now standard practice. Departmental barriers are giving way to Integrated Product Teams.

The generation that gave birth to the Titan family in the Research and Development phase are in the process of retiring. New tools are being developed to capture and communicate this corporate memory and associated lessons learned as we move into the future. Launch Operations Flow Management (LOFM) with its open system architectures and user friendly interfaces is one such tool presently under development that will tie the past and the future together.

The Titan IV flight hardware can be configured to support varied mission requirements, the facilities are adaptable to present configurations, scarred for future changes and flexible enough to support new requirements. Operational enhancements have been integrated into robust designs. The USAF has created an environment conducive for change and the contractors are empowered and have created the tools necessary to proactively manage change and continually improve the process and the products that will carry us on our quest for new frontiers.



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Reuse of Power Supplies

Gerard Woodlief - Martin Marietta MEC Senior Engineer

LC-41, LC-40 and SMARF

Cliff Gurr, Morris Worland, Ben Dusenberry

Martin Marietta Activations

CL1199 Trackage Mod Bolt Improvement

Stephen A. Ciulla - Martin Marietta Activations

Launch Operations Flow Management

Robert M. Day - Martin Marietta Advanced Programs

Concurrent Engineering

Don Haas and George Pestik - Martin Marietta Systems Engineering

Centaur Operations

Norm White - Martin Marietta

Honeywell Guidance Improvements

Michael Combs - Martin Marietta Systems Engineering (Denver)

High Performance Work Teams

Debbie Matteson - Martin Marietta Staff Administrator

Programmable Acrospace Ground Equipment (PAGE)

Ed Stephenson - Martin Marietta Operations

Joel Hagan - Martin Marietta Activations