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Air Force Okays Major Changes In Configuration of Titan III-C (January 29, 1968)

Titan III-D Moves Ahead After Year's Delay (April 8, 1968)

MOL/Titan III-M: A Status Report (April 22, 1968)

# Air Force Okays Major Changes In Configuration of Titan III-C

**Plan to substitute uprated Agena engine for Transtage engine is dropped; C-17 will be first vehicle to fly with modifications**

**by Frank A. Burnham**

LOS ANGELES—Several major modifications in the Titan III-C space booster proposed in a comprehensive product improvement plan (TECHNOLOGY WEEK, May 29, 1967, p. 24) have been adopted and will begin appearing in Vehicle C-17, now scheduled to be launched in early 1969 with the Dept. of Defense experimental Tactical Communications Satellite (TACOMSAT).

However, at least one principal modification—substitution of the Bell-built uprated Agena rocket engine for the Aerojet-General engine in the Titan III transtage—definitely has been dropped, Col. W. R. Taliaferro, system program director, told AEROSPACE TECHNOLOGY.

Col. Taliaferro said "an analysis of future mission requirements indicates the present transtage engine is more than adequate." He also ruled out, categorically, the possibility that the new high pressure, liquid hydrogen engine being built for the Air Force by United Aircraft Corp.'s Pratt & Whitney Aircraft Co., would be applied later to the transtage (A/T, Jan. 15, p. 15).

"Our missions do not require that kind of thrust or specific impulse," he said. "On the other hand, we do require the multiple restart capability and simplicity the present transtage gives us."

**New systems**—Beginning with Vehicle C-17, a new attitude control system featuring mono-propellant rocket motors using the same hydrazine fuel as the main transtage engines, the Univac 1824 airborne guidance computer, and a multiplexed instrumentation system will be installed on all future vehicles.

Major changes in thrust vector control system are expected to be implemented between Vehicles C-19 and C-21. The TVC tankage will be reduced. Flight experience has shown that considerably more TVC liquid than necessary was being carried. The TVC prevalve will be eliminated.

The Air Force has decided on a method that employs aluminum caps over the nozzle's injector ports to contain the TVC fluid. The caps are designed to burn away almost immediately after engine ignition and before vehicle steering is required. The pressure regulation system for the TVC system is being replaced by a simple "blow-down" system.

The malfunction detection and thrust termination systems are being eliminated on all follow-on production Titan III-C vehicles. The object, Col. Taliaferro says, is to "eliminate everything which initially was included to contribute to crew escape, but which does not contribute to reliability of the basic booster." The Titan III-C will not support manned missions.

About the same time, the 15-to-1 expansion ratio liquid fuel engine, being developed for the Titan III-M (MOL version), will be adopted for both the Titan III-C and D. The same engine with a cut-down thrust chamber skirt (giving a 12-to-1 expansion ratio) will be adopted for the Titan III-B. The B version does not have strap-on solid motors and the first liquid stage is ignited at sea level.

When these changes are completed, all Titan III family members, except the M version, will have "maximum commonality."

Change to a new all-attitude inertial guidance system will not occur until such a system is adopted for the Titan III-M. The "Carousel IV" system being developed for the Boeing 747 by General Motors Corp.'s AC Electronics Div. is front runner for the Titan III-M. When the firm completes development and flight test of the system, the MOL program office probably will fund integration of the system into its Titan III version. Only then will it be adopted for the Titan III-C general purpose booster.

**Fat-core Titan**—Asked what he foresaw as the launch vehicle beyond an uprated Titan III-C (Titan III-M, seven-segment solid rocket motors and a stretched first stage), Col. Taliaferro said:

"That is about the extent of the growth potential of the present Titan III. Beyond that, if and when a firm requirement exists for a booster in the 50,000 to 100,000 lb. payload class, I like the fat-core Titan with optimized 156-in.-dia. solid rocket motors."

Col. Taliaferro defined "fat core" as a Titan III vehicle with the diameter extended to 156 in. Four of the current Aerojet liquid-fuel engines are clustered and fed from common tankage.

Martin-Marietta Corp. has funded an in-house effort of this nature for some time and such a vehicle has been well defined.

Meanwhile, the Titan III-C following an 11-month stand-down is scheduled in June to support the first "replenishment launch" for the Initial Defense Communications Satellite System (IDCSS). The launch vehicle will be C-16, one of four remaining boosters ordered as part of the original Titan III R&D program.

Four military comsats will be placed in equatorial orbit at a near-synchronous altitude. The last Titan III-C launch in July 1967 was a multiple-payload mission in which three IDCSS spacecraft were launched to complete the operational system and three experimental vehicles were orbited.

Strong fears of Titan III Air Force/industry officials that the long stand-down would result in losing many critical specialists from the Cape Kennedy Air Force/contractor team responsible for assembly, checkout and launch apparently were unfounded, according to Col. Taliaferro.

**Lost a handful**—"Fortunately we managed to keep the good people busy. I don't think we lost more than a handful. Although I may squeeze my rabbit's foot just a little harder when we light off, I don't really feel our confidence factor has slipped."

"No one likes to mark time for an extended period, but I don't think we've suffered," Col. Taliaferro added. "I'm not planning any additional prelaunch tests or any special training. I look to the crews to do the same outstanding job they have in the past."

The long stand-down is the result of a tight defense budget. The Air Force originally planned to launch four vehicles a year in 1967, 1968 and 1969, but payloads scheduled for the last half of 1967 were off schedule.

Technically, the Titan III still is in its R&D phase, but for all accounts and purposes, has been operational since 1965 and carrying high priority payloads. Therefore, launch scheduling has been geared to an operational rather than flight test environment.

Vehicle C-5 will be flown, probably in August 1968, with a series of experiments to be conducted as part of the Space Experiment Support Program (SESP) (A/T, Jan. 1, p. 17). Vehicle C-15 will be launched in late 1968 or early 1969 with two Vela nuclear detection satellites aboard. Vehicle C-17, last of the R&D boosters and the first to include major changes, will be flown in early 1969.

**Not part of follow-on**—Vehicle C-18, an additional Titan III-C bought by the Air Force over and above the R&D program, but not part of the eight-vehicle follow-on production order, will be a backup to the C-15 and C-16.

If the four-launch-per-year schedule is followed in 1969-1970, three production vehicles will be launched during the remainder of 1969, four in 1970 and one in 1971. When a sufficient number of programs are approved and funded for a booster, a second follow-on production buy will be authorized.

Ideally, the Air Force said, the Titan III-C should be procured in lots of 12 or more.

Use of a new 35-ft. payload fairing for the IDCSS replenishment launch and extension of the fairing to 50 ft. for future programs will activate Pad 40 at Cape Kennedy's integrate-transfer-launch (ITL) complex and require modifications of Pad 41.

The mobile service tower (MST) and environmental shelter at Pad 41 will be modified prior to the June launch when the new 35-ft. fairing will be used for the first time. Meanwhile, Pad 40 will be reactivated and its MST and environmental shelter will be redesigned to accommodate both the 35-ft. fairing and a 50-ft. version.

"Then we'll have complete flexibility in terms of payload requirements," Col. Taliaferro explained. ■

# DOD Lists Top RDT&E* Contractors For Fiscal 1967

| | NAME OF CONTRACTOR | THOUSANDS OF DOLLARS |
|---|---|---|
| 1 | LOCKHEED AIRCRAFT CORP. | $708,779 |
| 2 | GENERAL DYNAMICS CORP. | 461,130 |
| 3 | GENERAL ELECTRIC CORP. | 439,090 |
| 4 | WESTERN ELECTRIC CO. INC. | 413,974 |
| 5 | McDONNELL DOUGLAS CORP. | 236,826 |
| 6 | NORTH AMERICAN AVIATION INC. | 236,165 |
| 7 | BOEING CO. | 220,320 |
| 8 | HUGHES AIRCRAFT CO. | 165,909 |
| 9 | MARTIN MARIETTA CORP. | 155,821 |
| 10 | WESTINGHOUSE ELECTRIC CORP. | 121,782 |
| 11 | AVCO CORP. | 112,172 |
| 12 | PHILCO FORD CORP. | 101,898 |
| 13 | RAYTHEON CO. | 97,624 |
| 14 | MASS. INSTITUTE TECHNOLOGY | 92,423 |
| 15 | TRW INC. | 90,011 |
| 16 | SPERRY RAND CORP. | 82,282 |
| 17 | AEROJET GENERAL CORP. | 80,277 |
| 18 | LING-TEMCO-VOUGHT INC. | 77,466 |
| 19 | UNITED AIRCRAFT CORP. | 75,989 |
| 20 | GRUMMAN AIRCRAFT ENGINEERING CO. | 74,260 |
| 21 | GENERAL MOTORS CORP. | 72,831 |
| 22 | JOHNS HOPKINS UNIVERSITY | 71,041 |
| 23 | AEROSPACE INC. | 70,827 |
| 24 | ARO INC. | 55,590 |
| 25 | RADIO CORP. OF AMERICA | 54,429 |
| 26 | BENDIX CORP. | 43,802 |
| 27 | SANDERS ASSOCIATES INC. | 39,407 |
| 28 | SYLVANIA ELECTRIC PRODUCTS INC. | 38,299 |
| 29 | HONEYWELL INC. | 32,694 |
| 30 | TEXAS INSTRUMENTS INC. | 32,233 |
| 31 | STANFORD RESEARCH INSTITUTE | 30,617 |
| 32 | INT'L BUSINESS MACHINES | 28,981 |
| 33 | FEDERAL ELECTRIC CORP. | 24,350 |
| 34 | BELL AEROSPACE CORP. | 23,318 |
| 35 | GLOBAL ASSOCIATES | 22,684 |
| 36 | ATLANTIC RESEARCH CORP. | 21,812 |
| 37 | GARRETT CORP. | 21,581 |
| 38 | GOODYEAR AEROSPACE CORP. | 21,169 |
| 39 | MITRE CORP. | 20,942 |
| 40 | PAN AMERICAN WORLD AIRWAYS INC. | 20,205 |
| 41 | THIOKOL CHEMICAL CORP. | 19,395 |
| 42 | RAND CORP. | 19,322 |
| 43 | SYSTEMS DEVELOPMENT CORP. | 19,078 |
| 44 | NORTHROP CORP. | 18,759 |
| 45 | UNIVERSITY OF CALIFORNIA | 17,353 |
| 46 | CORNELL AERONAUTICAL LAB. INC. | 17,111 |
| 47 | CONTROL DATA CORP. | 16,579 |
| 48 | COLUMBIA UNIVERSITY | 16,416 |
| 49 | INSTITUTE FOR DEFENSE ANALYSIS | 15,823 |
| 50 | INT'L TELEPHONE & TEL. CO. | 15,608 |

| | NAME OF CONTRACTOR | THOUSANDS OF DOLLARS |
|---|---|---|
| 51 | MARQUARDT CORP. | $ 15,463 |
| 52 | MAGNAVOX CO. | 15,296 |
| 53 | STANFORD UNIVERSITY | 14,875 |
| 54 | LITTON SYSTEMS INC. | 14,364 |
| 55 | COLLINS RADIO CO. | 14,227 |
| 56 | RADIATION INC. | 14,129 |
| 57 | GENERAL PRECISION INC. | 13,785 |
| 58 | UNIVERSITY OF MICHIGAN | 13,714 |
| 59 | IIT RESEARCH INSTITUTE | 13,517 |
| 60 | RESEARCH ANALYSIS CORP. | 13,287 |
| 61 | FAIRCHILD HILLER CORP. | 13,087 |
| 62 | VITRO CORP. | 12,497 |
| 63 | TELEDYNE INC. | 12,336 |
| 64 | HAZELTINE CORP. | 12,160 |
| 65 | BOOZ ALLEN APPLIED RESEARCH INC. | 12,074 |
| 66 | LTV ELECTROSYSTEMS INC. | 11,829 |
| 67 | FRANKLIN INSTITUTE OF PA. | 11,293 |
| 68 | CUTLER HAMMER INC. | 11,149 |
| 69 | UNIVERSITY OF ILLINOIS | 10,961 |
| 70 | KENTRON HAWAII LTD. | 10,648 |
| 71 | PA. STATE UNIVERSITY | 9,808 |
| 72 | FMC CORP. | 9,264 |
| 73 | MOTOROLA INC. | 9,001 |
| 74 | RYAN AERONAUTICAL CO. | 8,254 |
| 75 | ITEK CORP. | 7,846 |
| 76 | TRACOR INC. | 7,677 |
| 77 | ALPINE GEOPHYSICAL ASSOC. INC. | 7,284 |
| 78 | PLANNING RESEARCH CORP. | 7,238 |
| 79 | EG&G INC. | 6,826 |
| 80 | BATTELLE MEMORIAL INSTITUTE | 6,804 |
| 81 | CORNELL UNIVERSITY | 6,713 |
| 82 | ITT GILFILLAN INC. | 6,693 |
| 83 | DYNALECTRON CORP. | 6,601 |
| 84 | ELECTRO OPTICAL SYSTEMS INC. | 6,440 |
| 85 | WHITTAKER CORP. | 6,399 |
| 86 | TECHNICAL OPERATIONS INC. | 6,389 |
| 87 | CURTISS WRIGHT CORP. | 6,290 |
| 88 | BUNKER RAMO CORP. | 6,165 |
| 89 | U.S. NAT'L AERO SPACE AG | 6,070 |
| 90 | EWR FAIRCHILD INT'L JV | 5,900 |
| 91 | CLEVITE CORP. | 5,738 |
| 92 | MONSANTO RESEARCH CORP. | 5,733 |
| 93 | HERCULES INC. | 5,705 |
| 94 | BURROUGHS CORP. | 5,636 |
| 95 | INTERSTATE ELECTRONICS | 5,626 |
| 96 | UNIVERSITY OF WASHINGTON | 5,618 |
| 97 | KAMAN AIRCRAFT CORP. | 5,552 |
| 98 | WATKINS JOHNSON CO. | 5,413 |
| 99 | LOCKHEED SHIPBUILDING CONSTRUCTION | 5,365 |
| 100 | ITT ELECTRO PHYSICS LAB. | 5,337 |

*** Research, Development, Test and Evaluation**

# Titan III-D Moves Ahead After Year's Delay

## Construction of launch complex slated to begin in September; status report on Titan III-D and III-B programs

LOS ANGELES—Architectural engineering and design work in preparation for modifying Space Launch Complex 4 East (SLC-4E) at Vandenberg AFB to accept the new Titan III-D now is under way. Army Corps of Engineers officials here say the work is "on schedule" in accordance with the revised timetable established last year.

The Titan III-D was initially scheduled to enter the active inventory this year and construction was to have been complete in July 1968. The Dept. of Defense, however, deferred the program go-ahead for a year due to inadequate funds. The construction schedule set for 1967 now is in effect for 1968, an engineer spokesman told AEROSPACE TECHNOLOGY.

The plan sets Feb. 1 to July 1, 1968, for the A&E design phase. From July 1 to Aug. 1, requests for bids will be sent out and processed. A contract is due to be let that will enable the 10 month construction period to begin by Sept. 1.

Modifications to the launch complex, originally built to support the Atlas/Agena vehicle combination, will cost an estimated $6 million and will include:

- Changing the oxidizer and fuel holding area to accommodate the Aerozine 50 and nitrogen tetroxide ($N_2O_4$) fuel and oxidizer used by all Titan launch vehicles,
- Adding 30 ft. to the mobile service tower and adding a new bridge and crane to handle heavier loads (Titan III-D 120-in. solid propellant booster motors),
- Constructing an environmental control area at the top of the mobile service tower for the Agena and its payload,
- Raising the umbilical tower,
- Adding new work platforms to facilitate on-pad buildup of the solid motors and permit them to be serviced,
- Constructing a solid rocket motor (SRM) storage facility,
- Using explosion-proof electrical systems on the pad,
- Redesigning the flame bucket and the water deluge system as required by the 2¼-million lb. thrust (at liftoff) solid booster motors, and
- Making minor modifications to the launch control center (LCC).

**Special purpose version**—The Titan III-D and an earlier special purpose version, and Titan III-B, which has been flying from SLC-4W for more than a year, are outgrowths of what the Pentagon first identified as the Titan III-X program in April, 1965. At that time, the Dept. of Defense announced the first increment of $16 million on a $98 million contract with Martin Marietta Corp.'s Denver Div. for the first X version, ultimately designated the B. The number of vehicles was not disclosed.

Air Force sources report that the vehicle is a "standard Titan III-A core without the Transtage (third liquid fueled stage) and certain operational kits designed for manned launches." It was made clear then that the vehicle was designed to accept a variety of upper stages, including the Agena, Centaur, Transtage, or other new upper stages.

Development and flight test of the Titan III-B subsequently became shrouded in secrecy. News releases consisted of a simple statement that a Titan III-B/Agena had been launched. However, informed sources say that the Titan III-B program has been marked by the total absence of a flight test phase. An "operational payload" was carried on the very first launch, they say, and on all subsequent launches totaling nine through mid-March. The first launch was July 29, 1966. Eight of the nine launches to date have been successful. On April 26, 1967, the Agena vehicle failed to achieve orbit. All Titan III-B launches go into polar orbit and Air Force spokesmen say "support classified missions."

**Five-segment motor**—The Titan III-D will be a more powerful version of the B vehicle with two, five-segment 120-in. solid propellant motors identical to those scheduled for production follow-on versions of the Titan III-C. The Dept. of Defense announced procurement of the D in Nov. 1967, with a fixed price incentive fee contract of $88,632,664 to Martin Marietta, the integrating contractor, for "design, fabrication, assembly and test." The number of vehicles included in the contract was not announced. On May 25, 1967, a three-and-a-half year contract totaling $59,850,000 was let to United Technology Center for 32 of the 120-in. dia. solid rocket motors for the D and the production follow-on version of the C.

The number of motors for the D was not disclosed, but the Air Force said that the C follow-on order was for "eight vehicles," indicating that this particular contracting action also included pairs of motors for eight D vehicles.

With the exception of contract announcements, the development of the Titan III-D has been cloaked in the same secrecy as the B. On Jan. 26, however, a high level briefing was held at Stapleton Field, Denver, where Air Force and contractor officials briefed top level NASA representatives on the complete Titan III family in the "approved program" which consists of the versions A through M. The Titan III-M is for the Manned Orbiting Laboratory.

The Titan III-D will use the Titan III "common core" which makes its debut with the first of the follow-on C production vehicles. The common core includes the first and second liquid fuel stages of the Titan III-C using the new 15:1 expansion ratio first-stage engine being developed for the Titan III-M.

The new engine features an extended ablative thrust chamber skirt which increases the expansion ratio. A total of 22 skirts already has been produced and static testing has proved the design at firing times double that expected in operation. In the Titan III-B, a 12:1 expansion ratio skirt will be used.

The common core is 91 ft. long and has a dry weight of 18,340 lbs. Both first and second stage are 10 ft. in diameter. The first stage is 74 ft. long and the second 17 ft. The new first stage engine is designed for a burning time of from 143 sec. to 150 sec. with an Isp of from 295 to 299.

**Total thrust**—Its total thrust ranges from 518,000 to 524,000 lbs. at altitude, compared with 470,000 lbs. for the R&D version of the Titan III-C. The second stage has a burn time of 205 sec., an Isp of 313, and a nominal thrust, at altitude, of 102,600 lbs. This is a little more than 2,000 lbs. above the current C. Station 296, the point where the second stage interfaces with the third stage, is considered the top of the standard core. At this point the D has some 84,000 parts compared to 117,000 for the follow-on C. An estimated 66,000 parts, or 79%, are common with the C.

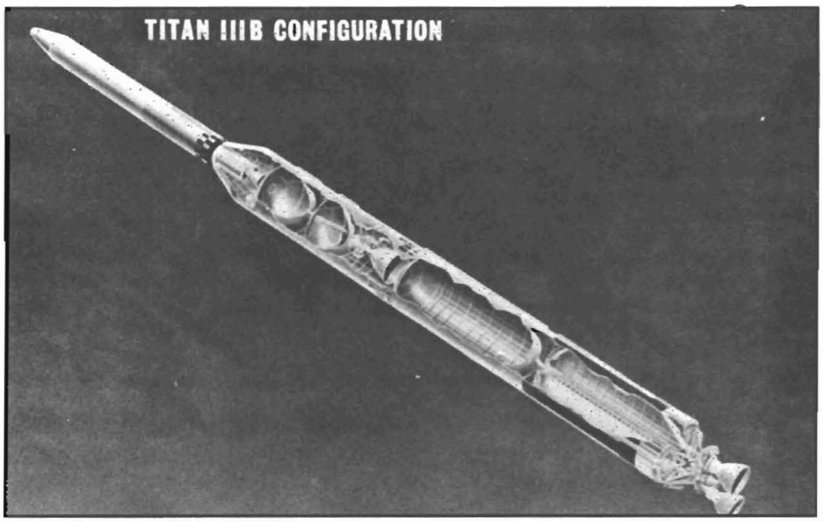
Emphasis on the entire family of boosters is on commonality, and the Air Force stresses that "the first two stages of all current models (first follow-on C is the departure point from the R&D vehicles flying today) are essentially alike with discrete kits added to meet special configuration requirements. After a thorough design review, optimum designs and manufacturing processes were selected and incorporated into the drawing system for the common core that is baselined across the Titan III family."

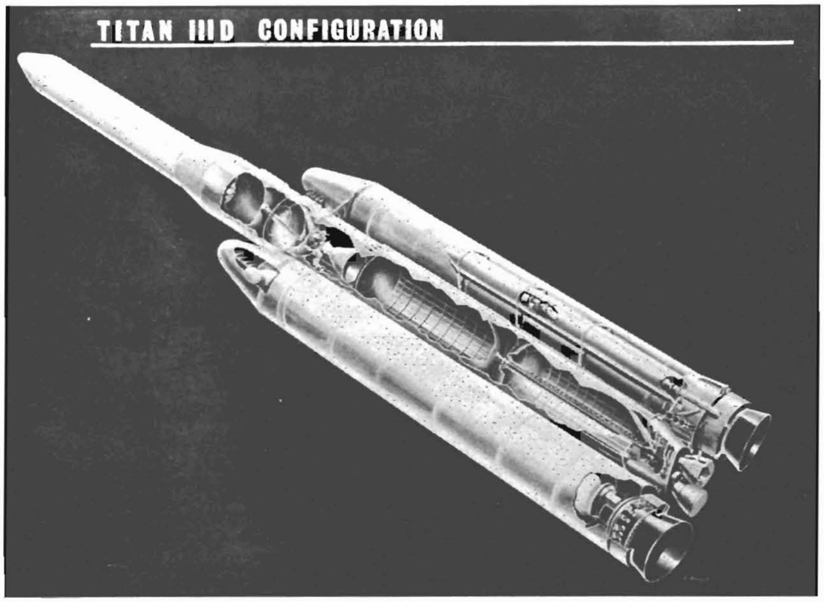
In B and D versions an equipment section located forward of the second stage is added to house guidance, flight controls, instrumentation and power equipment. Air scoops have been included at the base of the first stage to prevent exhaust recirculation. Both special purpose versions launched into polar orbit from Vandenberg AFB are equipped with the Western Electric/Remington-Rand Univac radio command guidance. The R&D versions, A and C, have inertial guidance systems supplied by the AC Electronics Div. of General Motors Corp. It was also revealed that both B and D will have a "yaw steering capability to achieve dog leg maneuvers around land areas."

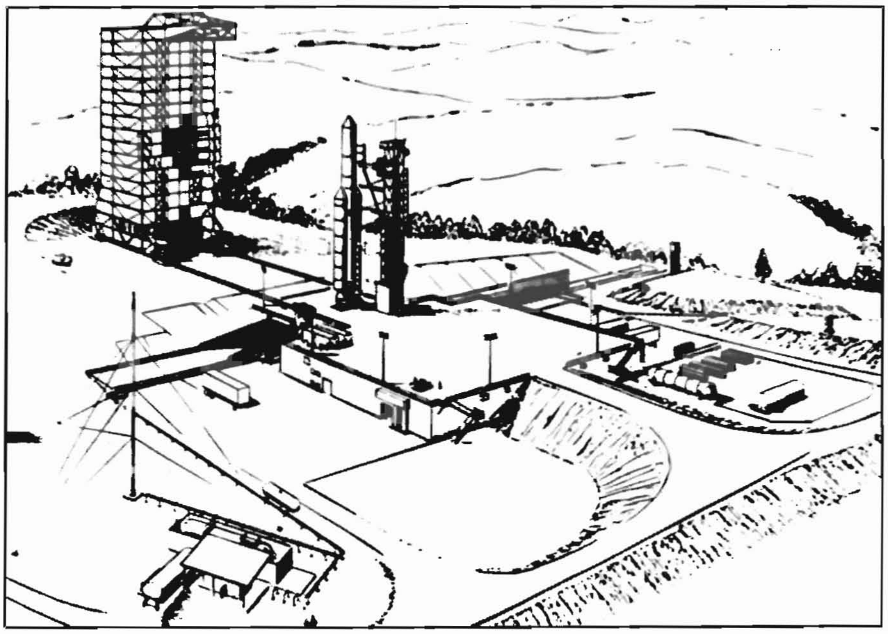
The Titan III-B, and it is presumed the D, uses an addressable remote multiplexed instrumentation system. Each remote multiplexer unit (RMU) handles 32 sensor data channels.

Data are transmitted to the converter by a pair of wires for conversion from analog to digital PCM format. An S-band transmitter for this system now is under development and will be flown first on a B in Jan. 1969.

**Boat-tail heat shield**—On the D, a boat-tail heat shield protects the first stage engines from the exhaust of the solid rocket motors. The equipment compartment located forward of Station 296 also differs from the B because of different D requirements. The Titan III-B uses 4-amp-hr. batteries. In the D transient load power supply, batteries have been increased to 25-amp-hr. units. Also on the D, the lateral acceleration sensing system (LASS) generates pitch and yaw commands to decrease vehicle



*Titan III-D Space Launch Complex 4 East is depicted above. The 4 West complex for the III-B is virtualy identical.*

angle of attack and thereby reduce bending loads. Scale drawings show the D (with Agena and adapter section) to be about 25 ft. shorter than the 177-ft.-tall Titan III-M.

The Agena configuration currently used with the B is the Agena D. It is 18 ft. long and 5 ft. in diameter. The payload compartment and fairing is the same diameter and extends the length another 28 ft. for a total of some 46 ft. It is surmised that the so-called uprated Agena, or Agena E, now under development by Lockheed Missiles and Space Co. and Bell Aerosystems Co., may replace the current Agena on the Titan III-D.

The five-segment solid rocket motors for the D will be identical to those produced for the follow-on C. The motor case is D6AC steel heat-treated to an ultimate strength of 195,000 psi. Each joint is a pin and clevis type held together by 240 cylindrical pins. Pins are hand fitted and held in place by a retaining strap. A gas pressure seal between segments is provided by an "O" ring.

Each segment contains approximately 72,400 lbs. of polybutadiene acrylic acid acrylonitrile composite bonded to the case wall. A 10-in. taper is provided for in the circular port cast longitudinally through the 10-ft. segment. The purpose of the taper is to provide the 10-sec. controlled tailoff at the end of web action time.

A rubber restrictor bonded to the propellant inhibits burning in the forward end of the segment. As a result, the propellant burns along its internal port and aft surface. A rubber insulator —silica-filled butadiene acrylonitrile— insulates the motor case from hot gases maintaining a normal temperature throughout firing. No thrust termination is provided for in D.

Initial thrust at sea level is 1.147,000 lbs. with a prelaunch weight of 511,000 lbs. including 424,000 lbs. of propellant. Web action total impulse is 108,034,000 lb./sec. (vacuum) and web action Isp is 266 lb./sec. (vacuum). Statistics are based on nominal performance at 60°F. NASA was quoted a "throw weight" for an Eastern Test Range (ETR) launch of 26,500 lbs. for the follow-on C and the D although the Agena is flown with the D instead of the Titan III transtage. This would give the D a capability from Vandenberg AFB into polar orbit of approximately 22,560 lbs.

**Ullage blowdown system**—Liquid injection thrust vector control is used as in the original C model, but a simple ullage blowdown system has been substituted for the complicated pressurization and fuel control system flown in the R&D version. Separate tanks for the nitrogen tetroxide (TVC fluid) and nitrogen (for pressurization) have been eliminated, along with the inter-tank structure and plumbing, including the main prevalve and auxiliary control valves which caused considerable trouble on at least one Titan III-C launch at Cape Kennedy.

Weight reduction achieved with the new system includes 800 lbs. in the nitrogen system, 5,800 lbs. in the TVC fluid system and 4,500 lbs. of inert weight—a total of 11,100 lbs. System maintenance requirements and costs also have been reduced.

The TVC system is capable of a vector angle of 5 deg. and a maximum side force of 110,000 lbs. It comprises 24 valves located in an area ratio of 3.5:1. Exit plane diameter ratio is 8:1. The valves are uniformly spaced on the nozzle's periphery and operate in groups of six. $N_2O_4$ is supplied to the valves through a toroidal manifold mounted above them. The valves are completely modulating from zero to full open and are controlled by electrical signals (0-10v) from the core.

Mission capability may be maintained with only five of the six valves operating in each quadrant. Aluminum caps, called pyroseals, over the nozzle injector ports contain the TVC liquid (A/T, Jan. 29, p. 21). The caps burn away almost immediately after engine ignition and before vehicle steering is required.

The ullage blowdown system consists of a single tank of $N_2O_4$ and $GN_2$ pressurized at 1,100 psi. Operation is permitted from 1,100 to 500 psi. Total length of the TVC tank has been reduced from 39¾ ft. to 28 ft. The complete solid rocket motor including five segments, forward and aft closures, forward fairing and nozzle is 85 ft.

Adaptability of the D to accommodate various payloads includes available payload instrumentation for 56 channels at 100 sps (bi-level) and four channels each at 400 sps, 200 sps and 100 sps (analog). These are channels available in excess of those required by the launch vehicle.

The Air Force reported that instrumentation modifications are planned to further increase the number of channels available to the payload.

Information on the payload-discrete signals generated in the B launch vehicle include one velocity discrete type and 11 timed discrete types. In addition to other equipment aboard, two velocity and two timed discretes are available for payload use.

Using the Agena as it presently does, D separation is not planned at the interface point. Rather, an adapter is provided for. Structural continuity is provided for at the interface point at 36 stringers each fastened with two bolts. On the other hand, in the B which also uses the Agena, standard NAS hardware at 12 longerons provide both shear and axial continuity ■

# MOL/Titan III-M: A Status Report

## First unmanned launch of full system could come in 1970 and manned shot in mid-1971; a detailed, comprehensive report on entire project

Los Angeles—First launch in the Air Force Manned Orbiting Laboratory program—an unmanned system qualification launch—could be conducted before the end of 1970, an Air Force spokesman told Aerospace Technology.

The first manned launch, he says, now is scheduled for "mid-1971." This timetable, however, is contingent on no further program stretchouts or serious technical difficulties. The program already is two years behind, primarily due to intentional action on the part of DOD and the Administration in stretching out the program definition phase and delaying the beginning of actual hardware development.

### Titan Schedule

**A total of 51 Titan III launch vehicles representing four different design versions are on firm contract and scheduled for production from January 1968 through December 1971, Aerospace Technology has learned.**

**They include nine Titan III-Cs (eight in the follow-on production order to the 17-vehicle R&D buy and one additional contracted separately before the production order), 12 Titan III-Ds, 23 Titan III-Bs and seven Titan III-Ms (MOL launch vehicle).**

**This schedule, a program spokesman says, "shows a firm production base over the next four years that will stabilize manufacturing and overhead costs and insure maintenance of high-quality skills and experience."**

**Production by year: 1968—11, 1969—12, 1970—16, 1971—10, with two vehicles (including first Titan III-M) straddling the Dec. '69/Jan. '70 period.**

**Martin Marietta Corp., Titan III integrating contractor, expects additional buys, however, for the company recently briefed NASA saying that "by 1970 the Titan III production rate is anticipated to be 18 vehicles per year or one every 20 days."**

**by Frank A. Burnham**

All major systems now are said to be under development.

Although the MOL program to date has been marked with minimal release of information by DOD, considerable technical data is available from unclassified sources. Compilation of this information now provides a more definitive picture of the huge Titan III-M/MOL/Gemini B combination than has heretofore appeared in print.

**Halfway mark**—With the program apparently at the halfway mark—32 months since President Johnson announced it on Aug. 25, 1965, and approximately 31 months until the earliest possible date for the first launch—it shapes up this way:

—length of 177 ft. from bottom of solid rocket booster nozzle to top of Gemini B;

—liftoff weight approximately 1,818,500 lbs.;

—liftoff thrust 3,160,000 lbs.;

—stage 1 thrust 524,000 lbs. (altitude ignition);

—stage 2 thrust 102,600 lbs. (altitude ignition);

—laboratory vehicle—approximately 51 ft. long, 14 ft. pressurized for living/working quarters and 37 ft. unpressurized housing vehicle systems and storables;

—atmosphere in crew compartment—31% helium, 69% oxygen at 5.0 psi;

—atmosphere in Gemini B—100% oxygen;

—mission profile—low altitude polar orbit, all manned missions now being considered for full 30 days.

Details of the B, C and D versions of the Titan III have been reported in the Jan. 29 and April 8 issues of Aerospace Technology. Differences unique to the M version range from major changes to minor modifications. Much commonality exists, however, and 66% or 59,400 parts of the 90,000 in the Titan III-M are common with the other versions using the so-called "standard core."

Weight of the MOL laboratory/Gemini B combination was estimated at about 30,000 lbs. This necessitated uprating both the solid propellant booster rockets and the first and second liquid propellant stages.

The Air Force in a recent briefing of NASA on the Titan III-M put its payload capability in low Earth orbit from the Eastern Test Range (ETR), Cape Kennedy, at 38,000 lbs. The rule of thumb for converting ETR "throw weight" to payload capability into polar or near polar orbit from the Western Test Range (WTR) at Vandenberg AFB, Calif., is 84%. This gives the Titan III-M a WTR "payload" of approximately 31,920 lbs.

Allowing for the "three sigma" performance margin normally mandatory as a safety factor in a manned mission, it appears that engineers are faced with keeping payload weights, which historically escalate, within strict limits while simultaneously nursing every bit of capability from the III-M booster. The M configuration flies without the third liquid stage or transtage.

**Stage O**—Two seven-segment, 120-in. dia. solid propellant rocket motors developing slightly more than 1.5 million lbs. of thrust each comprise what the Air Force calls Stage O. Each segment is 10.5 ft. long. The forward closure and nose fairing is 20 ft. long, the aft closure and 6°-canted nozzle is 16.5 ft. long and there is a 2-ft. interface structure between the aft closure and nozzle where the thrust vector control (TVC) system is mounted. Overall length of the solid motor is 112 ft.

The TVC system is the same as the D and follow-on production models of the C with exception that it is fully redundant. All functions are in the core autopilot except the valve drive amplifiers. Amplifiers are in the valves. Commands are redundant with one pair of wires for each pair of injection valves. TVC injection ratio is 2.9 to 1.

Thickness of the case walls has been increased to accommodate 920 psi Main Effective Operating Pressure.

The forward and aft closure grain design is same as the C but the individual segment grain design has been changed to "modified circular." The man-rated thrust termination system developed as part of the C program will be used. Port life has been increased from 7.5 to 10 secs. The nozzle has an expansion ratio of 9.18 and is of graphite cloth/rosette throat design.

Insulation has been thickened to increase burn time and a decreased-burning-rate propellant formula is to be used. Ground support longerons have been modified and other changes have been made to accommodate the increased loads.

Designated the 1207, the Titan III-M solid rocket motor (SRM) has an initial thrust at sea level of 1,397,000 lbs., with a web action total impulse of 152,339,000 lb./sec. (vacuum) and a web action specific impulse of 268.7 lb./sec. (vacuum). Nominal burn time is 127 sec. Pre-launch weight of each motor is 700,000 lbs. with 593,000 lbs. of propellant. Performance data is figured at 60°F.

**Test in April**—United Technology Center makes the 120-in. dia. solid rocket motors including those for the M. Informed sources say the first seven-segment motor may be test fired in the company's Coyote Canyon, Calif., facility before the end of April.

Stage 1, first liquid propellant stage, is being extensively modified. Its overall length will be "stretched" from 74 to 79 ft. Fuel and oxidizer is the same as used in the other Titan III launch vehicles but capacity has been increased.

The fuel tank is being extended 31 in. in length and the oxidizer tank 36 in. in length. Stage 1/Stage 2 staging bolts will be increased from 8 to 12 and have been increased from 0.75 to 1 in. in diameter.

Enlargement of the boattail will allow accommodation of the new 15.1 expansion ratio thrust chamber skirt.

Mating with the laboratory vehicle is accomplished with explosive bolts at eight longerons at a point 102 ft. above the Stage 1 engine skirt and about 105 ft. above the exit cones of the solid booster motors. A bearing pad on the laboratory insures the application of the load at the eight longerons.

Stage 1, fully loaded with fuel and oxidizer, will weigh 311,900 lbs. Nominal burning time has been increased to 170 sec. Thrust (at altitude) is 524,000 lbs. with an Isp of 299 sec. This is an increase of 46,000 lbs. at altitude over the current C. As reported earlier, follow-on Cs and the new D will have equal performance and will use the same engine.

In addition to the new skirt, Stage 1 engine modifications include changes to the combustion chamber, an improved turbine, a new gearbox, a dynamically stable injector, redundant wiring, strengthening of the frame and what the liquid engine contractor, Aerojet-General Corp., calls "durability improvements." All development items, the contractor points out, are associated with performance and reliability improvement and with redundancies for man-rating.

**Baffled injector**—Area ratio of the regeneratively cooled combustion chamber has been changed from 8.1 to 6.1 for the M engine. The chamber uses a baffled injector to achieve dynamic stability and has been tested extensively by Aerojet in a series of pulse or "bomb" tests.

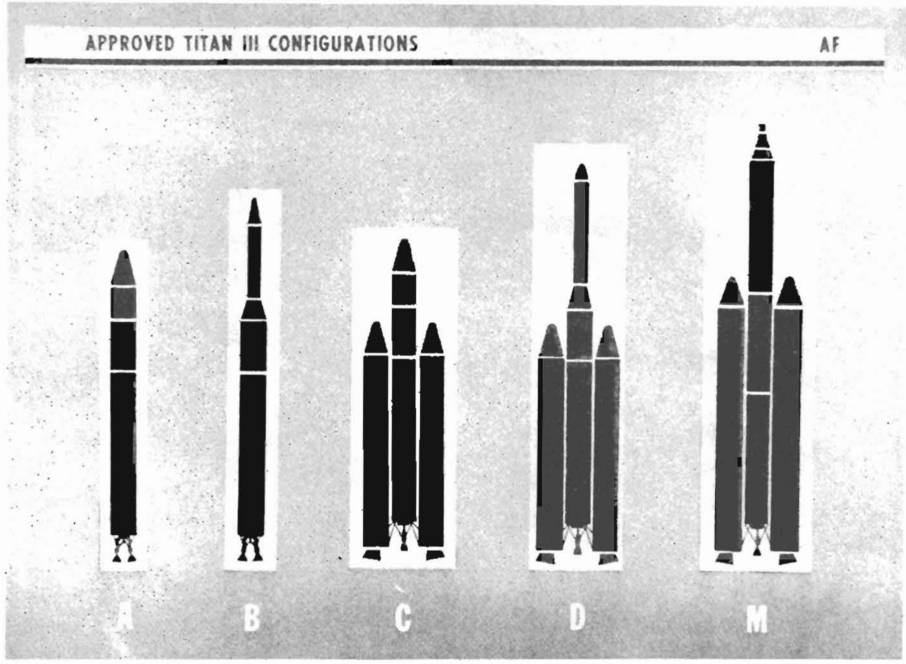
The chamber is reported to have an excellent stability recovery when subjected to "200-grain bomb" tests. Flight specifications include operation at chamber pressures ranging from 776 to 840 psia with propellant temperatures from 35° to 90°F and a maximum burnout ratio of 0.82.

In demonstration tests at Aerojet's Sacramento facility the engine was operated at a chamber pressure of from 750 to 870 psia, with propellant temperatures up to 100°F and with an actual burnout ratio of 0.67.

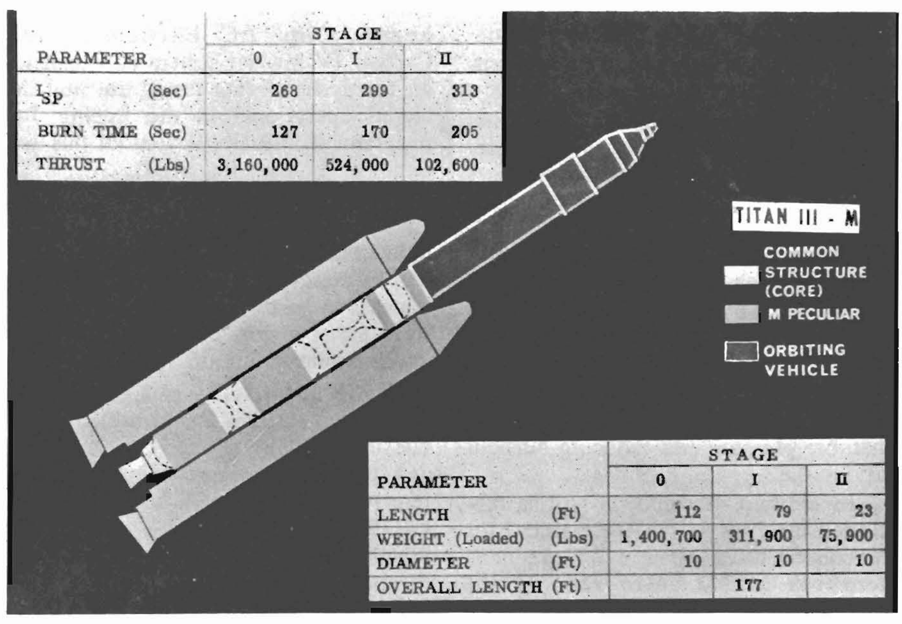
The 15.1 expansion ratio skirt has been tested exhaustively at values significantly exceeding flight specifications (A/T, March 25, 1968).

The Titan III-M gearbox has been modified to incorporate a revised high-speed shaft design and a modified lubrication system. The critical speed characteristics of the shaft and the load-carrying capacity of the turbine shaft bearings have been improved.

Critical speed has been increased from the Titan III-C's 17,000-21,000

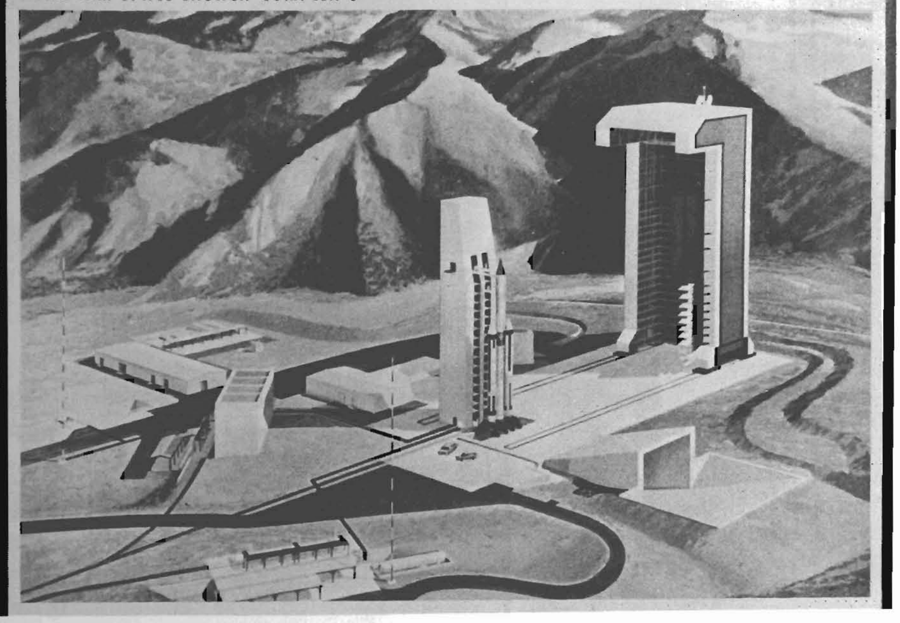



| PARAMETER | STAGE 0 | STAGE I | STAGE II |
|---|---|---|---|
| $I_{SP}$ (Sec) | 268 | 299 | 313 |
| BURN TIME (Sec) | 127 | 170 | 205 |
| THRUST (Lbs) | 3,160,000 | 524,000 | 102,600 |




| PARAMETER | STAGE 0 | STAGE I | STAGE II |
|---|---|---|---|
| LENGTH (Ft) | 112 | 79 | 23 |
| WEIGHT (Loaded) (Lbs) | 1,400,700 | 311,900 | 75,900 |
| DIAMETER (Ft) | 10 | 10 | 10 |
| OVERALL LENGTH (Ft) | | 177 | |

TITAN IIIM SPACE LAUNCH COMPLEX 6



rpm to 30,000 rpm. Maximum duration running time for the C gearbox is 165 sec. compared with the M's nominal 200. The gearbox actually was demonstrated at 300 sec.

Maximum temperatures on the high speed bearing were 310°F for the C vs. 280°F for the M. Lube pressure has been increased from 20 to 35 psi.

**Improved lubrication**—Modifications to the Stage 2 Aerojet engine are being studied in the areas of the frame, gearbox, redundant wiring, redundant shutdown capability, injector, and combustion chamber. The gearbox, which will feature improved lubrication distribution and increased durability, is the unit developed for but not incorporated in the Titan II Gemini Launch Vehicle.

Product improvement changes planned for the injector include seven dynamically stable baffle blades, modified fuel manifolds, improved fuel film cooling distribution and improved pattern distribution.

It is intended to "increase the structural and thermal load-carrying capacity to the levels achieved in the Stage 1 engine." Completion of modification and test of the Stage 2 engine is scheduled for mid-1969.

Current nominal specifications for the Stage 2 Titan III engine are chamber pressure 830 psia; propellant temperature 35° to 90°F; and burnout ratio up to 0.9. Design goals for the M stage 2 engine include ±5% tolerance in the chamber pressure and reducing burnout ratio to 0.82.

In addition, Hastelloy X will be substituted for Cres 347 as the material for the cooling tubes which will be reduced from 148 to 114. Area ratio of the nozzle exit cone is 49.2:1. Area ratio of the regeneratively cooled combustion chamber is 13:1.

Martin Marietta Corp., integrating contractor and airframe fabricator for the M, and Aerojet differ on performance specifications for the improved Stage 2 engine.

Martin quotes the thrust (at altitude) as 102,600 lbs., the burn time as 205 sec. and the Isp at 313 sec. Aerojet quotes thrust at 100,000 lbs. (nominal at altitude), duration 225 sec. and Isp (nominal) 310.3 sec. The Air Force will not specify which are correct.

Maximum flexibility in terms of launch time has been designed into the Titan III-M. Design requirements in this area call for the capability to count the vehicle down to T minus 27 min. and hold for up to 60 days.

The Titan III-M will have redundant guidance systems. Although it is reported that adoption of the General Motors Corp. AC Electronics Div.'s Carosel IV inertial system still depends on the system being tested out and declared operational in the Boeing 747 program, it virtually is assured this system will fly with the MOL.

Officials have set a requirement for an "all attitude" system and also have indicated that "no development program will be conducted." The Carosel system appears to be the only one within reach from either a time or externally-funded development point of view.

**BIGS and GIGS**—In the Titan III-M the two systems are identified as the booster inertial guidance system (BIGS) and the Gemini inertial guidance system (GIGS). BIGS will be primary and GIGS the backup system.

The design philosophy followed throughout Titan III-M is "that there will be no aborts because of a single failure." This, plus the man-rating requirement, made dual guidance systems mandatory. Fast malfunctions result in automatic switchover from BIGS to GIGS. Slow malfunctions are detected by monitored tracking data on the ground and by airborne displays monitored by the crew.

The malfunctioning system is identified by comparison of each system output with a third reference comprising accelerometers in the Lateral Acceleration Sensing System (LASS) and gyros in the Three Axis Reference Systems (TARS). Flight control and computer redundancy is provided by majority voted elements.

The Titan III-M will carry four separate LASS packages and three TARS packages. LASS 4 and TARS 1 provide the comparison referencing system used in identifying an impending malfunction.

Three redundant flight control systems provide steering through the TVC system during solid-booster-powered flight and engine gimballing during first and second liquid stage-powered flight. System 1 is primary for solid booster TVC, System 2 for first stage operation and System 3 for the third stage. Signals to the solid TVC go directly to the system and thence through dual redundant hydraulics and power supplies.

For first stage operation, signals initially go to majority vote actuators and then to primary and secondary hydraulic systems. Majority vote actuators also are in the loop for second stage control but only single hydraulics are employed.

Six separate battery power supplies are included in the design. Three provide power for flight control, instrumentation and malfunction detection system loads. One of these provides command receiver power.

A separate battery system supplies power for the inertial guidance systems. There are two transient power supplies to accommodate the requirements of payload separation ordnance, staging ordnance and solid rocket motor ordnance.

**CAGE functions**—Titan III-M vehicle checkout on Space Launch Complex 6 (SLC-6) at Vandenberg will be provided by computerized aerospace ground equipment (CAGE). CAGE functions fall into three categories—launch control, vehicle checkout and data monitoring.

Launch control tasks include performing automatic launch countdown; insuring safety and reliability of countdown through redundancy; monitor launch critical (hold) functions with redundant hardware and perform automatic safing and recycling procedures.

Vehicle checkout tasks include automatic and semi-automatic checks, isolating detected malfunctions to "replace black box level"; performing approximately 1,500 tests in 20-min. vehicle verification; and performing special tests in dynamic response, frequency, step and cross coupling.

Data monitoring capability provides for continuous PCM and discrete success criteria comparison on all channels; display of no-go data in real time; ambient/present readout of any monitor point on demand; display of requested PCM parameters on strip charts and analysis of trends on tank pressures. Out-of-tolerance parameters will be displayed automatically and the operator can command readout of any specific parameter.

CAGE equipment in the launch control center (LCC) includes two computers with an 80,000 bit shared memory, two sets of peripheral gear, control center interface equipment and the test engineer's console. Non-CAGE equipment includes range time and countdown associates and required consoles. In the aerospace ground equipment (AGE) building, CAGE installations include analog stimulation and response, discrete command, discrete monitor and majority vote discrete command equipment.

First of the 56-ton steel corners of the huge mobile service tower were delivered to the pad area last week by Alpha Steel Corp. Three of the corners will weigh the same. The fourth, to support the off-center weight of the huge folding platforms enclosing the MOL/Gemini B during erection, assembly and checkout, will weigh 85 tons.

A modification also has been made to the MST to provide for the off-center weight when the platforms are extended: a ninth truck has been added to the right side of the structure. Work on all four corners of the MST will be completed and deliveries will be made to the site during the next three weeks.

The first Titan III-M currently is scheduled to be accepted by the Air Force in Dec. 1969 or Jan. 1970. The remaining six vehicles are scheduled for April and Sept. 1969, and Jan., March, Aug. and Nov. 1970.

Little is known and the Air Force will not comment on the laboratory vehicle or Gemini B spacecraft beyond the meager information already released An Air Force MOL spokesman, however, has told AEROSPACE TECHNOLOGY that crew training is proceeding smoothly. All 15 aerospace research pilots assigned to the program have completed the intensive six-week "postgraduate" course at the Aerospace Research Pilot School (ARPS) at Edwards AFB, Calif.

The 15 already had completed the basic experimental test pilot course of seven months and the five-month course for aerospace research pilots.

Specialized MOL training will be conducted in a Gemini B simulator at McDonnell Douglas in St. Louis, Mo., and in an MOL laboratory simulator which, the spokesman said, will be constructed at Vandenberg.

**Transfer training**—The pilots currently are engaged in crew transfer training at Wright-Patterson AFB, Ohio, practicing exiting through a mockup of the Gemini B heatshield hatch and making their way through the access tunnel from the Gemini B through the Gemini B adapter section to the MOL pressurized compartment. This training is being conducted in the zero-G KC-135 aircraft. ■

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