Computer Performance Monitoring during the Centaur Launch Countdown

William F. Thomas*
NASA Kennedy Space Center, Cape Canaveral, Florida

During the past 15 years, the computer has been increasingly used to monitor launch critical measurements during the Centaur launch countdown. It has served as an aid to engineers, insuring that all critical measurements are operating properly prior to launch commit. A variety of computer programming techniques have been used to alert engineers of any critical measurement anomalies. At first, these techniques were quite simple, but gradually they have become more sophisticated. Special testing has become necessary to insure reliable computer monitoring. In the future, computers will play an ever expanding role in insuring proper system operation.

Nomenclature

A/C = Atlas Centaur
AMB = ambient
AUX = auxiliary
B = booster (abbreviation)
BOTT = bottle
BSTR = booster
C = Centaur
CEM = Centaur equipment module
CENT = Centaur (abbreviation)
CIF = central instrumentation facility
CK = check
CLD = closed
CNT = control
COMP = compartment
COOL = cooling
CPE = Centaur pulse code modulation (pcm) events
CUR = current
dc = direct current
DGF = degrees Fahrenheit (abbreviation)
DR = disable reference configuration
DS = delete analog set
ELECT = electrical
EMS = event measuring system
ENG = engine
ENV = environmental
ER = enable reference configuration
°F = degrees Fahrenheit
GMT = Greenwich mean time
GN2 = gaseous nitrogen
GSE = ground support equipment
GTR = gantry test rack
H = higher
He = helium
HTR = heater
ID = identification
INT = internal
INW = inches of water
IS = insert analog set
ISA = interstage adapter
L = lower
LADD = ladder
LNCH = launch
LOX = liquid oxygen
LQD = liquid
MAN = manifold
MON = monitor
MSL = missile
OTC = out-of-tolerance condition
PCOS = power changeover switch
PCUC = pressurization control unit—Centaur
PNEU = pneumatic
PR = pressure
PRESS = pressure (abbreviation)
psi = pounds per square inch
PU = propellant utilization
PWR = power
RC = reference configuration
REF = reference
REG = regulator
S/C = spacecraft
SECT = section
SEN = sensor
STG = stage
SUST = sustainer
TCC = test conductor console
TCD = terminal countdown demonstration
TEL = telemetry
TEMP = temperature
TH = thrust
VLV = valve
XFER = transfer

Presented as Paper 81-2397 at the AIAA/SETP/SFTE/SAE/ITEA/IEEE 1st Flight Testing Conference, Las Vegas, Nev., Nov. 11-13, 1981; submitted Nov. 24, 1981; revision received Sept. 13, 1982.

*Lead Electrical Engineer. Member AIAA.

Introduction

SINCE the first missile launches, every effort has been made to insure that all missile systems are operating properly prior to the actual launch. As the level of missile sophistication increased, procedures became more complicated, and engineers and technicians were stationed to watch certain critical measurements. During the early Apollo and Centaur programs, ground computers were first used for the checkout of the flight sequence (airborne computer program) and the inertial guidance system. Computers also were used to process data. However, most electrical and mechanical systems were both manually controlled and manually monitored.

In the last decade, improvements in computer technology have provided new "tools" for controlling and monitoring critical missile systems. Managers and engineers in the aerospace business have begun to use many of these capabilities. Computers now play a large and complex role in controlling and monitoring the Space Shuttle as well as other recently designed missile systems. Following this trend, computers have gradually taken on a major role in monitoring all flight and ground systems on the Atlas Centaur. The wide-body Centaur, which will be launched in the Space Shuttle cargo bay, will use computers to an even greater extent.

The chief problem in using computers to monitor missile systems is that of developing reliable, yet adaptable, software, such that only real problems are detected and brought to the attention of engineers. Adaptable software can be used and then modified, as required, when hardware changes become necessary. Developing a reliable system usually takes a considerable amount of testing, often called "debugging." However, in the case of an ongoing, fully operational program with repetitive launches, this "debugging" effort can pay off by providing a more comprehensive, yet less time-consuming, checkout of the missile system. There also is less chance of a real problem in the test data being missed due to human oversight.

Background

The Centaur vehicle has been used as a second stage on the Atlas and as a third stage on the Titan boosters. It has flown on a total of 66 missions, including the boosting of five Surveyors to land on the moon, an atmospheric probe mission to Venus, two Vikings to land on Mars, and the two Pioneers and two Voyagers which have traveled past Jupiter and Saturn. The Centaur has also boosted astronomical observatories into circular orbit and communication satellites into geosynchronous orbit.

The Centaur is currently being launched as the second stage on the Atlas booster from Complex 36 at the eastern launch site, Cape Canaveral, Fla. The wide-body Centaur currently is scheduled to fly in the Space Shuttle cargo bay in order to boost the Galileo and the International Solar Polar spacecrafts in separate launches in 1986.

The Centaur is a pressure-stabilized vehicle carrying liquid hydrogen as the fuel and liquid oxygen as the oxidizer. It is powered by twin engines capable of multiple starts. It is controlled by its own computer and inertial guidance system.

Critical systems which must be monitored prior to liftoff include: tank and pressurization bottle quantities and pressures, propellant quantities, propellant line temperatures, hydraulic control pressures and temperatures, environmental temperatures, battery voltages and temperatures, electronic package temperatures, bus voltages and currents, critical heater currents, presence or absence of critical commands, rf signal strengths, critical purge flow rates and delta pressures, guidance platform alignment, and ground and airborne computer communication.

The old, traditional method of monitoring these missile systems was that of having engineers and technicians watch red-lined strip charts and meters. There has even been an engineer in the blockhouse control level, stationed at a periscope with a telescopic lens, constantly watching the missile's different exhausts and physical structures. If this engineer noticed something strange or if any of the critically monitored measurements went beyond their red-line markings on the recorder or meter, the test conductor was immediately notified and could then hold the countdown.

If the automatic ignition sequence had begun, these red-line monitors commanded "cutoff" over the voice communication channel so that the test conductor would stop the automatic sequence. If the sequence was in the last 3 s prior to liftoff, the test conductor depressed the cutoff switch to shut down the Atlas engines.

Present System

Although engineers and technicians are still trained to monitor many of the same critical measurements, computers have now been programmed to monitor all critical measurements continuously. At this time, two separate computer systems are used to monitor these parameters.

The first set consists of two Harris Slash Four computers.[1] This system is in active control of the vehicle guidance and airborne computer systems. The system is also used to continuously monitor 176 critical analog measurements and 28 critical event measurements. In addition, 22 event measurements are checked one time at T – 50 s on launch day.

If any analog measurement is outside of its predefined limit or if any event measurement is not at its predefined state, the computer automatically cancels its permission to launch. This either prevents the start of the launch sequence prior to T – 31 s or stops the automatic sequence after T – 31 s. If the countdown reaches the last 3 s prior to launch, the computer will automatically shut down the Atlas engines. Thus, to a limited extent, this computer system has shutdown control of the launch sequence.

The second computer system consists of a Honeywell/General Electric 635 computer.[2] This system has a much larger memory and storage capability than the active control computer system and is used strictly to monitor vehicle and critical ground support measurements. Whereas the active control computer system has redundant hardware and strictly controlled software, the more passive monitoring computer system has limited backup capability and more informal software control.

Table 1 shows the various Centaur tests with the number of measurements monitored by this second computer system during each test. In addition, all vehicle and ground measurements can be displayed on video monitors for human review. Thirty of these monitor stations have a special switch that can address the computer system and request a display of any single measurement or group of measurements desired.

A system engineer located at one of these special video stations has several different video displays that he can select to be shown on his television screen. He can look at event measurements in real time or from the computer's storage of past data (Fig. 1). It is also possible to obtain analog measurements in real time or from the computer's storage, either on a graph (Fig. 2) or as a listing (Fig. 3).

The engineer can even monitor a special group of up to 16 real-time measurements, previously selected and listed (Fig. 4).[3] Finally, he may look at a combination of reference events and analog measurements on a special split systems monitor page (Fig. 5).[4]

These reference events are especially defined in the computer by the engineer himself. To illustrate using Fig. 6, when CEV 7X is in the "1" state and CEV 8X, CES158X, CES159X, CES160X are in the "0" state, the computer automatically prints the reference event on the video screen, notifying the engineer that the Centaur missile is being powered from its internal batteries (031 CENT ON INT). These reference events not only are used as notification of certain important engineering events, but also may be used to begin, change, or end various computer checks.

Table 1 Computer monitored Atlas Centaur vehicle tests

Test	Measurements	
	Events[a]	Analogs
Release sequence	54/1394	4
Power on	357/504	59
Integrated launch control	402/1016	61
Tanking	196/120	303
Flight events demonstration	392/711	175
Composite electrical readiness	265/580	169
Launch	348/409	412

[a] The first number of events are checked at T-5 min and T-31 s. The second number of events are time checked from a reference event.

```
1102 1201 AC-31 T C D J-6127
                   CURRENT                PAGE 3
                 EVENTS GRØUP 1
           DESCRIPTIØN          STATE      TIME

CN1423X  HE LQD DUMP VLV ØPEN     1     1053 16.05
CN1423X  HE LQD DUMP VLV ØPEN     0     1053 20.51
CN1422X  HE FLØW CNT VLV CLD      0     1053 32.59
CN1422X  HE FLØW CNT VLV CLD      1     1053 35.02
         RC SET 7 DISABLED              1054 13.14
         RC 108 ENABLED                 1055 55.43
CN1909X  PCUC ØN PNEU HE BØTT     1     1059 52.58
CN1412X  CENT HE BØTT PRESS       1     1059 52.82
CN1909X  PCUC ØN PNEU HE BØTT     0     1100 12.31
CN1412X  CENT HE BØTT PRESS       0     1100 12.85
CN1423X  HE LQD DUMP VLV ØPEN     1     1101 09.36
CN1423X  HE LQD DUMP VLV ØPEN     0     1101 12.31

EMSTIME  TIME EMS                 1     1050 00.06
EMSTIME  TIME EMS                 0     1050 12.02
EMSTIME  MASTER DELETED                 1050 13.73

      ▲EMS    ▲GTR  ▲CPE
CIF               ID 05▲           – 184 34
```

Fig. 1 Data display of real-time events.

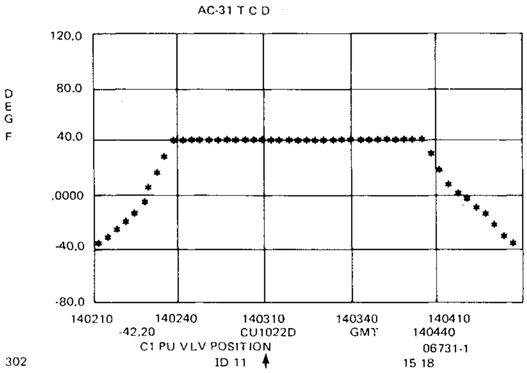

Fig. 2 Data display of a real-time analog graph.

```
                    ANALØG HISTØRY             PAGE 2
AE 2C            MAIN BATTERY CUR-HI          0 03134
   TIME        VALUE              TIME         VALUE

1602 06.13     2.745          1603 09.43       9.411
1602 06.22     3.529          1603 09.52       8.627
1602 09.41     2.745          1603 10.09       9.411
1602 09.49     3.529          1603 11.17       9.411
1602 15.78     2.745          1603 11.24       8.627
1602 15.87     3.529          1603 21.40       9.411
1602 19.05     2.745          1603 21.66       8.627
1602 19.14     3.529          1603 22.95       9.411
1602 19.83     2.745          1603 23.21       8.627
1602 19.91     3.528          1603 27.86       8.627
1602 21.03     9.411          1603 28.55       9.411
1602 34.29     8.627          1603 28.72       8.627
1602 34.48     8.627          1603 31.04       9.411
1603 04.09     8.627          1603 31.13       8.627
1603 06.16     9.411          1603 33.37       9.411
1603 06.24     8.627          1603 33.71       8.627

               ID 05▲
```

Fig. 3 Data display of an analog measurement listing from computer storage.

All of this computer display capability gives the engineer or manager a thorough visibility into all systems, as needed. And while the computer is providing all of this visibility and data display, the computer is running checks of its own—checks which have been previously defined and programmed.

Programming Methods

There are several methods used to program a computer to monitor measurements.[5] The first, and easiest, is used to monitor the status of event measurements.

The method uses an event matrix stored on a computer disk which may be brought into the computer and compared with present event information. This can be done once at any instant of time or the matrix can be monitored continuously. Any errors between the programmed matrix and the present information is reported to the operator on a special video screen. This special screen, which is constantly monitored, is called the red-line monitor page on the active control system and the out-of-tolerance (OTC) page on the monitoring system (Fig. 7).

A second computer method is called time event analysis. Only the monitoring computer system is programmed to use this technique, which is used to check the proper sequence and timing of certain event measurements that monitor critical control and logic circuits. A key event, such as the test conductor's start of the ignition sequence (AP1161X in Fig. 8), starts a computer timer which verifies that subsequent events (numbers 1-6 in Fig. 8) are activated at the proper times. The

```
                      AC-28 LAUNCH SAMPLE TEST

GMT 14 33 19 ENVIRØNMENT CNT 36A              PAGE 007

01 CN1626P   AUX GN2 LINE PRESS        1733. PSI   07010-1
02 CN1563P   ENV GN2 SUPPLY 36A        292.7 PSI   07004-4
03 CN1562T   A/C INLET GN2 36A         76.53 DGF   07003-2
04 CN1560T   S/C CØMP DUCT TEMP        65.09 DGF   07002-2
05 CN1347P   S/C CØMP DUCT PRESS       19.48 INW   06776-1
06 CN1271P   ELECT CØMP DUCT PR        10.62 INW   07122-1
07 CN1547T   ELECT CØMP DUCT TEMP      67.26 DGF   07000-1
08 CN1273P   THRUST SECT HTR DUCT      10.62 INW   07123-4
09 CN1557T   TH SECT DUCT TEMP         62.57 DGF   07001-1
10 AN1793P   ATLAS TH SECT DUCT PR     .0000 INW   07012-1
11 AN1353T   ATLAS TH SECT HTR         64.31 DGF   06777-4
12 AN1791P   PØD CØØL DUCT PRESS       19.38 INW   07011-1
13 AN1828T   PØD CØØL DUCT TEMP        63.80 DGF   07013-3
14 AN1829T   PØD CØØL DUCT TEMP        63.80 DGF   07019-1
15 AN1928T   PØD TEL CØMP TEMP         63.80 DGF   07020-1
16 AN1344T   XFER RØØM AMB TEMP        19.20 DGF   07021-1

CIF                 ID 13▲             ·943 31
```

Fig. 4 Data display of a predefined analog page.

```
1604 11.45             AC-31 TCD TEST
               SYSTEMS MØNITØR PAGE EXAMPLE       PAGE 6
503                BEGIN MØNITØR TEMP           1604 09.65
504                 INSERT A64 LNCH             1605 09.24

                 ENVIRØNMENT CNT 36A PAGE 2
01 CN1626P   AUX GN2 LINE PRESS       -36.14 PIA    12632-3
02 CN1563P   ENV GN2 SUPPLY 36A       267.3 PSG     12710-N
03 CN1562T   A/C INLET GN2 TEMP       102.3 DGF     12707-2
04 CN1560T   GSE TEMP MØN SEN 3       75.89 DGF     12706-N
05 CN1347P   PAYLØAD DUCT PRESS       .5882 INW     12672-N
06 CN1547T   CEM INLET TEMP           59.01 DGF     12703-3
07 CN1271P   CEN DUCT PRESS           19.27 INW     12664-N
08 CN1557T   ISA INLET TEMP           94.40 DGF     12705-N
09 CN1273P   ISA DUCT PRESS           16.58 INW     12665-3
10 AN1353T   TH SECT HTR ØUTPUT       86.90 DGF     12673-3
11 AN1793P   TH SECT HTR DUCT PR      .2352 INW     12724-N
12 AN1828T   PØD CØØL DUCT MSL        55.96 DGF     12725-N

CIF                ID .02▲
```

Fig. 5 Data display of a systems monitor page.

```
031 CENT ØN INT        CN 0509      P       7 9
     CEV 7X  1       PCØS INT CMD
     CEV 8X  0       PCØS EXT CMD
     CES158X 0         CENT PWR BUS 1 ØN
     CES159X 0         CENT PWR BUS 2 ØN
     CES160X 0         CENT PWR BUS 3 ØN
1      SMP04
2      SMP06
3      SMP08
4      DR031
5      ER622
6      ER736                  7
7      IS035
8      DS073
```

Fig. 6 Reference event as programmed in the computer by the systems engineer.

```
1401 24.31    AC-29 T C D  J-6127
                     CURRENT             PAGE 4
                     ØTC PAGE

MEAS NØ          DESCRIPTIØN          STATE   RC     TIME

AP1674T      B2 FUEL IGNITER VLV       L1     02   1351 10.72
AP1673T      B1 FUEL IGNITER VLV       L1     02   1351 10.82
AP1675T      ENG CNT PNEU MAN.         L1     02   1351 10.82
AP1675T      ENG CNT PNEU MAN.         L1     02   1351 28.42
AP1673T      B1 FUEL IGNITER VLV       L1     02   1351 28.52
AP1674T      B2 FUEL IGNITER VLV       L1     02   1351 28.52
AP1528D      SUST MAIN FUEL VALVE      H2     31   1354 40.32
AF1001P      LØX TANK HELIUM           H2     20   1400 32.73
AF1001P      LØX TANK HELIUM           H2     20   1400 35.63

AP1673T      B1 FUEL IGNITER VLV       L1     02   1258 45.85
AP1674T      B2 FUEL IGNITER VLV       L1     02   1258 45.95
AP1675T      ENG CNT PNEU MAN.         L1     02   1258 45.95
AP1026P      BSTR LØX REF REG          H2     02   1342 23.21
AF1001P      LØX TANK HELIUM           H2     20   1345 22.91
AF1001P      LØX TANK HELIUM           H2     20   1345 23.41

          ▲EMS ▲GTR ▲CPE                  ▲LL  ▲CPA
CIF                 ID 12▲            –18 47
```

Fig. 7 Out-of-tolerance page showing measurements that are out of limits.

```
670 PRESTART CK 9        WT 09                5
        AP1161X  1       TCC START SWITCH

1          SMP04
2          SMP06
3          SMP08
4          ER689
     1     SE1002X  1          0.10          0.50        SEQUENCER CØUNTING
     2     SE1001X  0          0.11                      SEQUENCER HØLDING
     3     AP1609X  1         19.31                      ENG FUEL TANK PRESS
     4     AP1610X  1                                    ENG LØX TANK PRESS
     5     AP1064X  0         20.10          2.00        STG 1 TANKING RDY
     6     CN1058X  0         24.00          7.00        PRESTART LADD CØMP
```

Fig. 8 Time event analysis program.

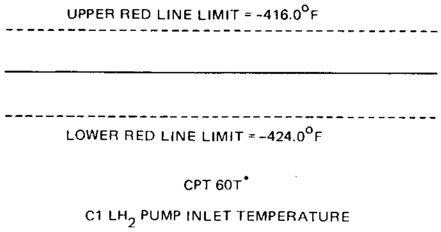

Fig. 9 Computer predefined analog limit.

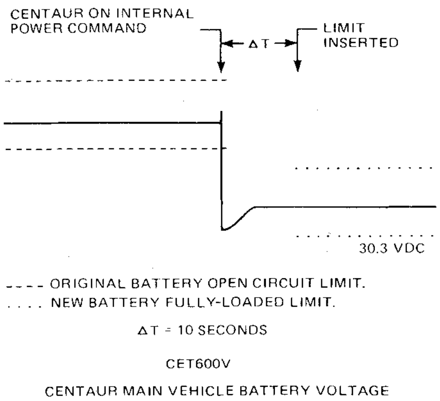

Fig. 10 Time delay between a command and a new analog limit.

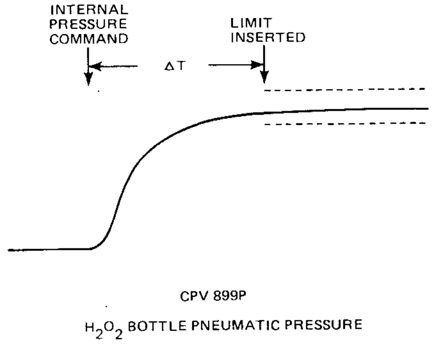

Fig. 11 Time delay between a command and an analog limit.

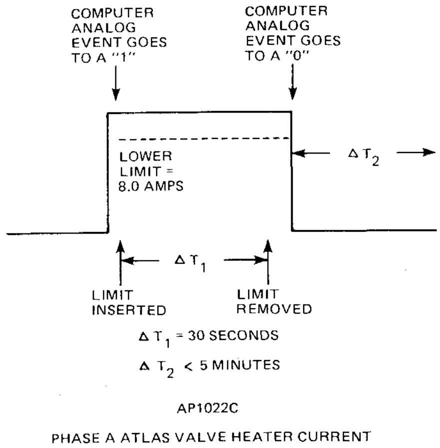

Fig. 12 Computer-generated event inserts and removes an analog limit.

most important use of this technique is that of checking the airborne computer's time-critical flight sequence.

Other programs, such as the one shown in Fig. 8, check the automatic launch sequence events which are time-critical from T – 31 s to T – 0. The time-event analysis method also is used to check other time-delay logic circuits in various critical ground support systems.

A third computer method, called an analog limit, is used by both computer systems and essentially does the job of a human strip chart monitor by placing an upper or lower limit (or both) on any analog measurement (Fig. 9). If a measurement leaves this limited band, an OTC or "red-line" condition is reported by the computer on either system's special video screen.

The major difficulty in monitoring analog limits by a computer is the false triggering of OTCs by random "noise" or transients. A slight transient, perhaps caused by manual switching, can cause an analog measurement to go OTC for only a few milliseconds and produce an apparent anomaly. A "noisy" measurement could produce the same false indication. These false indications take time to research and can be a real nuisance.

One way to prevent random "noise" and transients from causing OTCs is to use filtering techniques to dampen or eliminate transients. The first use of filters occurs at the data input to the computer. These filters are quite basic and are designed to have as little impact as possible on the accuracy of the data. It must be remembered that these systems, especially the monitoring computer system, are used to display data, and an accurate display is important to the engineer using the system.

Transients often are important to the system engineer. They can show the engineer the overall system's response to a change or command. For example, in Fig. 10, the battery voltage is required to recover to 30.3 V dc minimum within 10 s of the transfer to internal command. If it cannot recover in that amount of time, there is a strong possibility that the battery is weak and should be replaced. Therefore, in order to maintain accuracy, data sampling techniques remain rather simple at the data input to the computer.

The basic data sampling method employed for analog measurements by the active control computer consists of taking five samples, rejecting the highest and the lowest, and averaging the remaining three. In the case of event data, the control computer reports the state of three out of five samples.

The monitoring computer system, samples analog measurements at various rates, depending on the normal noise of the measurement. These rates are predetermined by the system engineer or data specialist. In addition, each measurement must change by a certain predetermined magnitude for the computer to recognize a new value. Finally, both analog and event measurements must remain at a certain level for continuous data samples before the computer will accept the value. The number of continuous samples can be changed in real time, but is usually set at two continuous samples.

Separate, more complicated filtering has been used for the computers' own monitoring of measurements. This filtering is often designed for the specific measurement. For example, the active control computer has a special 10 s timer for range safety signal strength measurements. In order for the computer to report an OTC, the measurement must drop below 0.5 V dc continuously for at least 10 s.

Another method used to prevent false OTCs by known transients employs a somewhat different and more complicated programming technique. This different and fourth programming technique is called analog time analysis. Both systems are capable of using this method. However, the method requires an extensive analysis of test data in order to place a special limit on a measurement at, or for, a predefined time. In some cases, a limit is placed on an analog measurement only after a predefined time from a discrete command has elapsed. This, in essence, waits for all transients to be dampened out. Figure 10 illustrates how the time delay between a command and an analog limit insertion is programmed for the Centaur main battery voltage when the vehicle load is applied. In this case the computer is programmed to delay 10 s after the internal power command before inserting the new, fully loaded battery limit. This programming technique must also be used when the airborne propellant tanks and when the airborne pressurization bottles (Fig. 11) are taken to flight pressures.

Ocassionally there is no discrete command available for time analysis programming at the instant a transient is expected. To deal with this possibility, the monitoring computer system can generate its own discrete "analog" events. This is a programmed event which is activated when an analog measurement reaches a certain predefined level. When the measurement reaches this level, the computer automatically activates the analog event. This event can then be used to install or delete an analog limit.

One example of the use of an analog limit and event combination is illustrated in Fig. 12. The Atlas engine valve heater is controlled by a thermostat mounted on the valve. Previous temperature data have shown that this heater should never be off for more than 5 min after the start of liquid oxygen loading at approximately T – 65 min.

When the heater is on, its current, as measured by AP1022C, should always be greater than 8.0 A. Therefore, an analog event has been set at 8.0 A. Each time the current level increases above 8.0 A, the analog event is turned on. But each time the current level drops below 8.0 A, the analog event is turned off. The computer-generated analog event not only indicates exactly when the valve heater was cycled on, but also can be used to insert an analog limit for a predefined minimum time. Using time event analysis, the computer also can time how long the heater is off. If the time ever exceeds 5 min, an OTC is reported on the video screen.

System Operation

In order to insure reliable computer control and monitoring, computer programs must be extensively checked prior to launch. Many of the most complicated programs go through development testing prior to use with the vehicle. These tests usually consist of several special computer analyses using data tapes from previous missile tests and launches. After these analyses have been performed successfully, a program is considered ready to use with the vehicle.

On each vehicle, many routine tests are run prior to the launch countdown. Table 2 shows the ground support and vehicle testing that is performed with computer verification programs active. These tests help to insure reliable software, accurate measurements, and fully operational hardware prior to the actual launch countdown.

Table 2 Centaur tests supported by computer measurement verification

Vehicle tests	Control system	Monitoring system
Release sequence	No	Yes
Power on	No	Yes
Integrated launch control	No	Yes
Tanking	Yes	Yes
Flight events demonstration	No	Yes
Composite electrical readiness test	No	Yes
Launch countdown	Yes	Yes

In the past, several critical ground support equipment problems have been discovered by computer verification and monitoring programs. In 1975 during the final vehicle electrical test on a Titan Centaur, the monitoring computer's initial event matrix check could not be matched to the current event data. A pyrotechnic squib simulator had been activated, apparently overnight. After further investigation the problem was attributed to the simulator itself. The simulator was replaced and the test was completed the next day.

Without the computer's discovery of this problem, it might not have been found until the day after the test during the engineers' time-consuming, manual review of the data. This could have necessitated a repeat of the entire test. The computer's early detection of the problem led to a timely and complete analysis of the problem, saving an estimated two days of additional work.

More recently, the monitoring computer system detected a problem during the Atlas Centaur launch countdown. Just prior to picking up the count at T – 90 min, the gaseous nitrogen heating unit failed and went off the line. This unit is a critical part of the environmental control system which maintains the proper supply pressure to the inlet of the vehicle air-conditioning units. These units process and maintain the proper temperature, pressure, and humidity for both the Atlas' and the Centaur's engine thrust sections and electronic equipment areas. They also maintain a proper environment for the spacecraft inside the payload nose fairing.

The problem was traced to a faulty control relay which was replaced. However, when the unit was brought back on line, the monitoring computer immediately reported an OTC on the payload duct pressure. The pressure measurement was reported to have gone out of band high. The panel operator had failed to notice the pressure spike on his panel meter. However, once the computer had "flagged" the measurement, a review of both the strip chart and the computer's data memory confirmed the anomaly.

Apparently, when the gaseous nitrogen heating unit was brought back on line, all of its pressure was forced into the payload air-conditioning unit. Much of this pressure was subsequently sent up the payload duct to the payload nose fairing.

Immediately a design team was formed to analyze the data and confirm that no damage had been done either to the spacecraft or to the launch vehicle. While this analysis was being made, the countdown was continued.

Prior to the T – 10 min hold, the design team agreed that no real damage had been done. The computer's immediate detection of the problem led to a timely and thorough analysis which resulted in a successful launch that was on schedule.

Conclusion

Computers have been used with great success to monitor all critical systems on the Atlas Centaur vehicle. The examples given are only a sample of the many measurements that are presently monitored. Several times, critical hardware problems and setup mistakes have been detected. Often, testing problems have been detected when they actually occurred that would not have been found until the post-test data review.

During launch countdown, with today's complicated electronic systems, computer monitoring has become a necessity. As systems become more complicated, the use of computers to monitor and command these critical systems will continue to grow. Already new capabilities are being planned for future checkout and launch sequences.

When the Centaur is placed into Space Shuttle cargo bay, it will be loaded with propellants automatically by an extension of the present active control computer system. A special tanking console will be built solely for this purpose. In the future, carefully programmed computers will control and monitor most of the flight and ground equipment. Engineers no longer will have to perform extensive post-test data review by hand, but will depend more and more on the computer's real-time analysis. Engineers will also have more freedom to watch video screens especially programmed for any information they desire to monitor, while still knowing that the computer is continuously monitoring all critical measurements.

References

[1] "Computer Controlled Launch Set System Requirements," General Dynamics Convair, Doc. ICT 37-92, 1973.

[2] "Digital Data Base Verification System," NASA Doc. TM-670, 1978.

[3] "Atlas Centaur Information System: Realtime Data Monitor System," NASA Doc. TM-642, 1979.

[4] "User's Guide for CIF Data Display System in Support of Atlas Centaur Launch Vehicles," NASA Doc. CD 106.02, 1975.

[5] "Computer Program Development Specification for the Realtime Software System," NASA Doc. TM-676, 1980.