Preliminary Analysis of the Impact of Power Cycling on CTA-21 Equipment Reliability

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This article presents the preliminary findings of a study being made at CTA-21 to determine whether Deep Space Station control room equipment power may be turned off to conserve energy. The results of reliability analysis indicate that there may be some correlation between the observed increase in failure rate and cycling of equipment power in the eight-month study period.

I. Introduction

The DSN Energy Conservation Project has been investigating modifications to Deep Space Stations at Goldstone, California, in regard to energy conservation and cost reduction. One of these modifications is to selectively turn off certain electronic equipment during periods of nonuse or low activity. Significant energy savings are expected to result, especially when equipment control is automated in the future via the computer-based Utility Control System. However, a key question in considering this procedure is whether cycling of electrical power will change equipment reliability and thus impact DSN maintenance and operations activities or cost.

The DSN Equipment Compatibility Test Area (CTA-21) at JPL, Pasadena, was selected as a test site. This is the CTA-21 control room in building 125 where electronic and air conditioning equipment is presently turned off on weekends. The use of the CTA-21 control room provides field observations of equipment reliability under conditions closely representing a Deep Space Station's environment.

Tentatively the study is divided into two phases. Phase one, which is the substance of this article, consists of data collection and performance of a preliminary analysis. It covers the period of April through November 1977, examining overall failure trends. Phase two is a detailed correlation analysis of failures with possible causes. Each phase will be discussed in detail later.

II. Field Observations and Data Collection

After examining CTA-21 past failure and maintenance records, it was decided that the existing records were not of sufficient detail or comprehensiveness to support the study. Therefore, in conjunction with CTA-21 management and staff, a special equipment event log was implemented. This form, as shown in Fig. 1, provides both the DSN Energy Conservation Project and CTA-21 with an unique source of information consisting of:

(1) Equipment failures, including references to equipment event reports (EER's) when applicable

(2) Power turnoff periods

(3) Commercial power outages

(4) Air handler failures

(5) High ambient control room temperatures

(6) Equipment modifications through engineering change orders (ECO's)

(7) Other installations, removals, calibrations, and maintenance

The log utilizes two coding groups to assist in data processing and interpretation. The first group is the event code, which specifically identifies the nature of the event reported. The second group code provides categorization of the type of equipment involved. The equipment event log serves not only the purposes of the study but also makes available to CTA-21 management and engineering a useful maintenance record. Since outstanding events are referenced in subsequent order in the log, relevant actions can be traced and monitored for optimum performance.

The equipment at CTA-21 represents nearly ninety percent of the equipment located in the control room of a typical Deep Space Station. At times, this consists of over one hundred individual cabinets of widely varying types of electronic equipment. Therefore, the equipment was divided into ten system categories to simplify analysis:

(1) Telemetry

(2) Communication

(3) Radio frequency

(4) Command

(5) Monitor and control

(6) Radio metric

(7) Simulation and test

(8) Timing

(9) Facility

(10) Software

No special turnoff procedure is used at CTA-21. However, individual cabinets and systems are turned off in no particular sequence before general power is removed. The control room air handlers are allowed to run an additional thirty minutes after equipment turnoff to remove residual heat. This procedure was initiated when a significant rise in temperature-related failure rates was noted prior to the preliminary study period. Likewise, individual equipment is turned on after general power is restored.

III. Data Study and Analysis

Initial CTA-21 equipment event data have been processed for the thirty-four-week period from April 4, 1977, until November 23, 1977, and were divided into seven subperiods designated as either "experimental" or "control" periods. Experimental periods are defined as those time intervals during which equipment power was turned off on weekends. That is, those contiguous groups of weeks where equipment power is off for nominally two days (weekends) and equipment power is on for five days. In control periods, the power was on all seven days of the week. The control periods, listed in Table 1, start with a weekend during which power was left on and cover the period until power is next turned off.

Only failure and power turnoff events were included in this preliminary phase one analysis. No attempt was made to determine possible causes of individual failures. Turnoff of power at CTA-21 is conducted on a noninterference basis with the operations schedule, which leads to widely varying study period lengths. The statistics of hourly failure frequency (or rate) was computed to allow comparison of control and experimental study periods.

The distribution of daily failure rates occurring in each subperiod over the entire study period is shown in the time-line bar charts in Fig. 2. The time-line bar chart was produced to reveal any significant distribution patterns, and to display overall trend. Tables 1 and 2 compare failure rates to indicate any significant effect of power turnoff on equipment reliability.

IV. Results of the First Phase Study

Inspection of the above time-line bar chart does not directly indicate any particular repetitive pattern. However, the overall 34-week failure trend was downward as shown by Table 1. Furthermore, the failure rates in both period types decreased over the duration of the study. One explanation could be that turning off equipment power over long time periods extends equipment life and is manifest in lowered failure rates. Other possibilities include reduced station activity and unreported failures. These hypotheses will be examined in more detail during the second phase.

Table 1 indicates that failure rate increased during periods of weekend power turnoff, and that the overall experimental period failure rate exceeds the aggregate control period failure rate by 73%. Table 2 shows that the majority of failures occurred in the telemetry and communication systems equipment. However, the greatest sensitivity to power turnoff was exhibited in the monitor and control system, although all systems show an increase in failure rate during experimental periods.

Figure 3 shows the time distribution density of failures as a function of elapsed time. The distribution for control periods exhibits a somewhat uniform density with considerable random variation. Since CTA-21 is normally manned during the week, usually no observations are made of failures that occur on weekends. They are reported when discovered during the five-day work week. This explains the marked decrease in failures on weekends. The distribution of failures after power turnoff shows an apparent 2.5-day cycle of unknown significance, whereas a simple "one cycle" exponential distribution would tend to suggest a strong relationship between equipment failure and power turnoff. This phenomenon will be further explored in detail during phase two of the study.

V. Significance of Results

The initial phase of this study shows an increase in failure rate during weekend turnoff periods. However, the results are based on only 282 failures occurring over 34 weeks. The adequacy of the data sample was tested, and data confidence intervals were determined to the 95% confidence level as shown in Table 3.

The resulting confidence intervals indicate that the computed failure rates are at best rough approximations. With an objective of reaching a 20% confidence interval (±10% confidence limit) it was determined that a possible 13 additional months of data would be required. Since new data may have a major effect upon final results, conclusions at this stage are undecisive.

The next phase of study not only will benefit from a larger data base, but also detailed correlation analysis will be performed. Correlation analysis will indicate relationships between failures and other events such as air handler malfunctions, high ambient temperatures, equipment modifications, life-cycle, etc. Failures thus identified may be eliminated from data being investigated for relationships to turnoff periods. The objective of phase two will be to identify equipment that is sensitive to power turnoff, thereby providing a criterion by which electronic equipment may be selectively chosen for power shutoff to conserve energy.

Acknowledgement

The cooperation and assistance of G. H. Winn and A. Salazar of CTA-21 in making this study are acknowledged.

Table 1. Total CTA-21 failure rate for 34-week study period

Period type	Weeks	Failures	Total hours	Pwr on hours	Failures/hour	
					Control	Expt
Control 1[a]	8	72	1344	1344	0.0536	
Expt 1[b]	8	91	1344	875		0.1040
Control 2	6	52	984	984	0.0528	
Expt 2	5	29	864	563		0.0515
Control 3	2	11	336	336	0.0327	
Expt 3	1	7	168	118		0.0596
Control 4	4	20	624	624	0.0321	
Total percentage	34	282	5664	4844	0.0471 100%	0.0816 173.1%

[a]Control periods (eqpt. not turned off): 1. April 2–May 27; 2. July 23–September 1; 3. October 8–October 21; 4. October 29–November 23.
[b]Experimental periods (eqpt. turned off on weekends): 1. May 28–July 22; September 2–October 7; 3. October 22–October 28.

Table 2. Failure rates for the ten system categories

System	Failures	Percent of total	Failures/hour		Percent difference
			Control period	Expt period	
Telemetry	85	30.1	0.0143	0.0244	70.8
Communication	58	20.6	0.0110	0.0141	29.1
RF	34	12.1	0.0058	0.0096	66.8
Command	31	11.0	0.0055	0.0084	52.6
Monitor	31	11.0	0.0040	0.0116	192.6
Metric	16	5.7	0.0024	0.0052	111.3
Simulation	14	5.0	0.0024	0.0051	58.5
Timing	11	3.9	0.0015	0.0039	153.6
Facility	2	0.7	0.0003	0.0006	111.3
Software	0	NA	NA	NA	NA
Total	282	100%	0.0471	0.0816	+73.1%

Table 3. Data confidence and sample adequacy

Period type	Failures/hour	Confidence interval	
		Limit	% of rate
Control 1	0.0536	±0.0152	±28.5%
Expt 1	0.1040	0.0260	25.0
Control 2	0.0528	0.0167	31.5
Expt 2	0.0515	0.0232	45.1
Control 3	0.0327	0.0269	82.1
Expt 3	0.0596	0.0222	37.4
Control 4	0.0321	0.0161	50.4
Total control	0.0471	±0.0090	±19.1%
Total expt.	0.0816	±0.0174	±21.4%

EQUIPMENT EVENT LOG
STATION: CTA-21
DATE: 8/01/77 DAY: MON

EVENT CODE:
B = BROKEN E = ECO M = MISC
C = CALIBRATION F = FAILURE
D = DEFECTIVE I = INTERMITTENT

GROUP CODE:
A = ANALOG FAC = FACILITIES
CA = CABLES L = LOGIC P = PWR SUPPLY
CO = CONNECTOR M = MECH O = OTHER

LOG NO. REF. DATE	GMT		EQUIPMENT	EER #	WA	EVENT CODE	GROUP CODE	HISTORY LOG	DESCRIPTION OF EVENT	ACTION
1229 6/26	1900		CPA 1			F	L	CMD	SIA #17 (UNUSED PORT) FAILED WRAPAROUND TEST	
1230 6/10	2130		PRA COMP INTERFACE			F	L/0	METRIC	COMPUTER INTERFACE FAILED WRAP-AROUND TEST	UNIT FROM 14, WORKED ON BY DAVIES (SPARE)
1231 6/30	1930		COMM BUFF 3			F	L/0	COMM	CB#3 DF LIGHT FAILS TO LIGHT. UNIT APPEARS TO PASS DATA PROPERLY	LED ON ORDER 07/29/77
1232 7/17	1400		DIS 1 MAG TAPE			C	A	MONITOR	READ ERROR ON BOTH MAG TAPE UNITS	MASTER OK
1233 7/21	1800		DIS 2 LP			F	L	MONITOR	L/P INOPERATIVE	
1234 7/21	1100		COMM BUFF 2			E	L/0	COMM	ECO 77.177 STARTED	
1235 7/21	0300		TPA 3 SEQ DECODER			F	L	TELEM	SEQ DECODER INOPERATIVE	
1236 08/01	1400		TCP PAPER PUNCH	38550		F	L/0	TELEMETRY	UNABLE TO PUNCH TAPE, ERRATIC	CORRECTED
1237 8/01	1430		CMF VARIAN			M	0	COMM	PREVENTIVE MAINT. PERFORMED ON PRINTER/PLOTTER	
1238 8/01	1500		TCP PHOTO READER	38549		F/I	L/0	TELEMETRY	ERROR IN LOADING PROGRAMS	CORRECTED
1239 8/01	1530		MDA OPS. SW.	38552		E	0	SOFTWARE	RECEIVED LATEST VERSION OF PROGRAM. DMK-5106-OP-B	ERROR TO ECO 76.042
1240 8/01	2000		RF LINK	38551		E	FAC/0	RF	CLOSEOUT OF ECO 77.027. INSTALL RF LINK JPL TO HUGHES	

Fig. 1. CTA-21 equipment event log

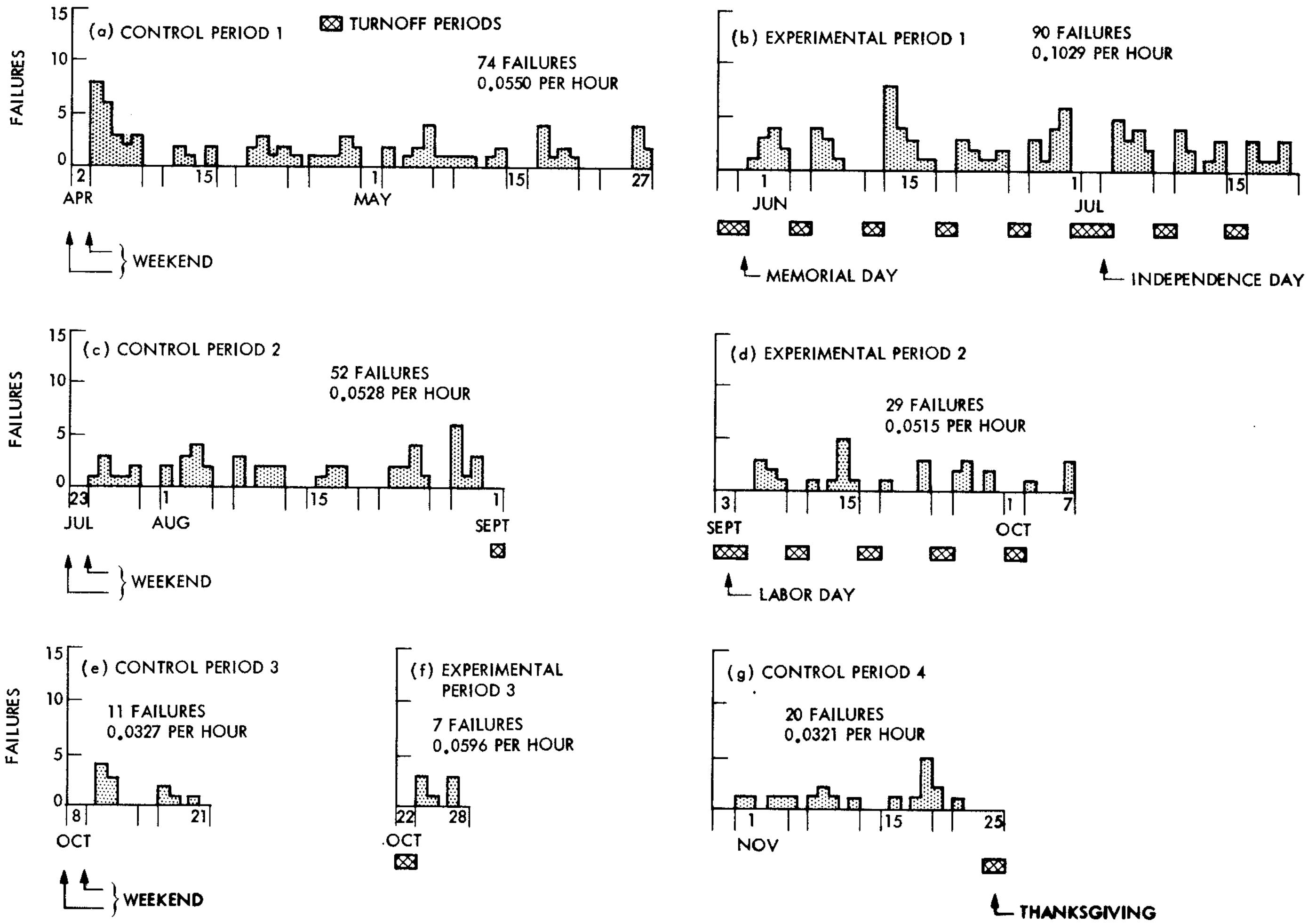

Fig. 2. CTA-21 equipment failure time-line chart

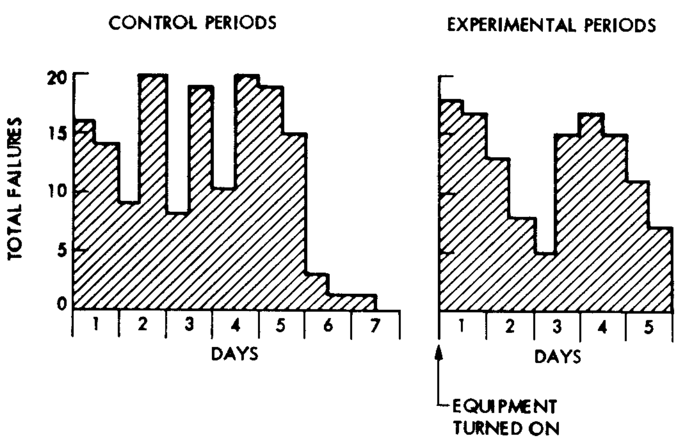

Fig. 3. Time distribution of CTA-21 failures for first phase data (April - November 1977)