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TANK MONITOR AND CONTROL SYSTEM (TMACS) PERFORMANCE ANALYSIS Under Steady State Conditions

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Abstract: A means to predict the performance impacts to the TMACS computer system prior to further increases in the TMACS point configuration is studied. A series of CPU utilization measurements are made on the TMACS production and development computers. These measurements are under steady-state operating conditions for I/O point processing and remote terminal support. The data from these measurements are used to derive formulas that are then used to project CPU utilization for other configuration profiles. A configuration profile is described for (1) the current TMACS production system, (2) the maximum capacity of the current TMACS production system, and (3) a much larger target system, which reflects the anticipated size of the monitoring system for the upgrade project, W-314. The derived formulas are used to calculate CPU utilization for each of these configuration profiles. The formulas are validated by comparing the calculated with the measured results for the current production configuration. An analysis is performed that shows that the current system of 1,600 points can be expanded to 4,000 points without any changes. Furthermore, the current system can be expanded to 10,000 points to meet the requirements of the target system with the planned purchase of new-generation hardware and modifications to the logging and delta-check routines.

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TANK MONITOR AND CONTROL SYSTEM (TMACS)
PERFORMANCE ANALYSIS
Under Steady-State Conditions

April 23, 1996

By

Robert B. Bass and Steven J. Washburn

Table of Contents

1.0	EXECUTIVE SUMMARY	3
1.1	OVERVIEW	3
1.2	DESIGN OBJECTIVE	3
1.3	SYSTEM PROFILES	4
1.4	RECOMMENDATIONS AND CONCLUSIONS	6
2.0	TECHNICAL ANALYSIS	8
2.1	INTRODUCTION	8
2.2	CPU UTILIZATION MEASUREMENTS	8
2.2.1	Background Processing	8
2.2.2	I/O Processing	9
2.2.3	Point Processing	9
2.2.4	Remote Telewindow ¹ Processing	10
	APPENDIX A - TMACS Release 9.1 Profile	11
	APPENDIX B - Target System Profile	12
	APPENDIX C - Background CPU	13
	APPENDIX D - I/O Processing	14
	APPENDIX E - Point Processing of Analogs	15
	APPENDIX F - Point Processing of Discretes	16
	APPENDIX G - Remote Window Processing	17

¹Telewindows is a registered trademark of Gensym Corporation.

1.0 EXECUTIVE SUMMARY

1.1 OVERVIEW

The Tank Monitor and Control System (TMACS) monitors and collects various field instrument sensor readings (points) from the waste storage tanks in the 200 East and West Tank Farms and K Basins. TMACS provides continuous monitoring of status and alarm information. Currently, the TMACS workstations are in the Computer Automated Surveillance System (CASS) Central Facility and the East and West shift offices. Appendix A provides a profile of the TMACS configuration applicable to this report.

During January and February of 1996, the TMACS development team conducted an analysis of the TMACS central computer system. The purpose of this analysis was to develop a means to project the performance impacts to the TMACS computer system prior to further increases in the TMACS point configuration.

In the last half of 1995, TMACS experienced system performance problems that heightened the need for performance measurements. During that time problems with the TMACS vendor's software product, G2², from the Gensym Corporation, caused a rapid increase in CPU utilization. This required TMACS personnel to shut down and restart the system approximately every 10 to 15 days to restore acceptable performance levels.

Installation of the latest release of G2[®] (Release 4.0) permanently remedied the problem of increasing CPU utilization over time. It also fixed another problem TMACS had encountered, large memory "leakage" over time. Currently, the TMACS's CPU utilization and memory usage is stable and no longer requires periodic shutdowns and restarts.

1.2 DESIGN OBJECTIVE

In this document we present performance measurements for our current system configuration and the projected TMACS target configuration. TMACS's primary performance requirement is to maintain CPU percent utilization at or below 50 CPU-% during steady-state operation.

Throughout this document we use the unit of measurement "CPU-%" to indicate CPU percent utilization. This unit represents the actual central processing unit (CPU) time the computer's operating system allocates to the G2[®] program, as a percent of maximum time available. A measurement of 50 CPU-% (the design objective) would indicate that the computer's CPU expends only half the time the operating system has made available to G2[®].

²G2 is a registered trademark of Gensym Corporation.

The following four functional processing areas define steady-state processing in TMACS:

- (1) **Background Processing** - processing associated with system overhead. Background processing is dependent on the number of points and other items configured in TMACS that require G2[®] to expend CPU time. It is independent of activity that operators initiate and activity from field instrumentation;
- (2) **I/O Processing** - processing associated with system interfaces to external field instrument inputs and outputs (e.g., Acromag, Enraf);
- (3) **Point Processing** - processing associated with delta checking³, instrument limit checking, alarm limit checking, rate-of-change limit checking, and sensor logging to disk for analog and discrete points;
- (4) **Remote Telewindow[®] Processing** - processing required to maintain remote TMACS workstation displays.

This report does not include an analysis of the effects on CPU utilization due to transient processing (e.g., alarm processing, rate-of-change) and operator functions (e.g., trend displays, alarm acknowledgements). We have assumed that such transient processing will be adequately handled by the 50 CPU-% reserve that will be available if TMACS meets the design objective. We have justified this assumption based on observations of the behavior of a previous version of TMACS; the system was running at 88 CPU-% for several months and could handle all transient processing. We anticipate that we will provide more formal and detailed transient performance measurements for TMACS as the system grows.

1.3 SYSTEM PROFILES

The table below provides a profile of the following TMACS system configurations:

- The current system load (TMACS Release 9.1, January 1996);
- A maximum capacity load based on the current system running at 50 CPU-%;
- The projected target system load, which meets the anticipated requirements of Project W-314 (see Appendix B for the description of the point-processing profile).

³ delta means the threshold value (determined by sensor type) by which the sensor reading must change for the sensor to be processed.

System Parameter	Current System Loading	Current System @ 50 CPU-%	Target System Loading
Number of Points	1,640 Analog: 1590 Discretes: 50	4,000 Analog: 3000 Discretes: 1000	10,000 Analog: 6000 Discretes: 4000
Average Polling Frequency	Analog: 8.4 pts/sec Discretes: 1.5 pts/sec	Analog: 60 pts/sec Discretes: 100 pts/sec	Analog: 400 pts/sec Discretes: 625 pts/sec
Number of Device I/O Ports	6	12	16
Instrument Readings Input Rate from Bridge to G2®	Analog: 8.4 pts/sec Discretes: < 0.1 pts/sec	Analog: 60 pts/sec Discretes: 4 pts/sec	Analog: 400 pts/sec Discretes: 10 pts/sec
Average Instrument Readings Input Rate per Port	1.4 pts/sec/port	5 pts/sec/port	26 pts/sec/port
Point Processing (delta not exceeded or no state change)	Analog: 8.1 pts/sec Discretes: 0 pts/sec	Analog: 50 pts/sec Discretes: 0 pts/sec	Analog: 360 pts/sec Discretes: 0 pts/sec
Point Processing (delta exceeded or state changed)	Analog: 0.3 pts/sec Discretes: < 0.1 pts/sec	Analog: 10 pts/sec Discretes: 4 pts/sec	Analog: 40 pts/sec Discretes: 10 pts/sec
Number of Remote Terminals	4	6	20
CPU Utilization	15 CPU-%	50 CPU-%	200 CPU-%

The CPU utilization figures in the table above are calculations from formulas that fit the performance measurement data. Section 2.0, Technical Analysis explains the measurement. We also took several measurements of the current production system's CPU utilization over time, under steady-state conditions, using the G2® performance meters. The calculated CPU utilization value for

the current system loading configuration matches actual measured values for the current production system within +/- 1.0 CPU-%. This close correlation between the calculated value and the measured values helps validate and increase our confidence in the formulas.

The next table shows the breakdown of the CPU utilizations, by functional processing area, for each of the three system configuration profiles in the previous table.

Functional Processing Area	CPU Utilization (CPU-%)		
	Current System Loading	Current System @ 50 CPU-%	Target System
Background Processing	8	14	29
I/O Processing	3	6	19
Point Processing	2	26	140
Remote Terminals	2	4	12
Total CPU Utilization	15	50	200

1.4 RECOMMENDATIONS AND CONCLUSIONS

Our analysis shows that the current TMACS will not meet our design objective to stay at or below 50 CPU-%, during steady-state operation, for the target system loading. However, while making our performance measurements we identified several areas of improvement that could immediately lower CPU utilization on the main TMACS processor. These include:

- Background Processing - background processing in a 10,000 point target system will require 29 CPU-%. We can reduce this significantly, to approximately 4 CPU-%, by replacing each point's old-style trend charts and its accompanying time/date displays. The new-style trend charts, which are available in G2®'s Release 4.0, are more efficient and have an improved time-axis label. The format of the new time-axis labels obviates the use of time/date displays;
- Logging to disk - the point processing routines expend over 50 % of their time logging points to disk. We can develop a GSI⁴ driver for the slave workstation that would off-load most of the logging overhead to the slave processor. We estimate that this would reduce CPU utilization for the target system by approximately 15 CPU-%;

⁴GSI is a trademark of Gensym Corporation.

- Analog Delta Check - the analog point processing routine expends approximately 30% of its time on the delta check. The percent CPU utilization in the target system would drop by approximately 95 CPU-% if we move the delta check from the analog point processing routine in the G2® code to the bridge code. The bridge code would then only send those analog points that exceed delta. This is similar to the way the bridge code now processes discrete points, which it only sends to G2® when there is a state change.

These modifications alone would reduce the projected CPU utilization on the target system from 200 CPU-% to 65 CPU-%. TMACS could operate below the design objective of 50 CPU-% with its next hardware upgrade. Even today's technology can provide the means to meet this performance level. For example, the Sun⁵ UltraSPARC⁶ provides almost twice the CPU processing power as the Sun® SPARC20®.

Purchase of new computer hardware (or upgrades) is consistent with the TMACS project plan to upgrade the main computer system periodically, on a two to three year cycle. This approach provides a means to maintain system reliability and to meet growth demands. The TMACS project also plans to continue to exercise the option in the maintenance agreement with the G2® vendor to implement future releases of G2®.

Since TMACS went online, in January of 1993, on a Sun® SPARCstation⁷ platform running G2® Version 2.0, we have seen a tenfold increase in processing capability. This increase is the result of a combination of upgrading hardware, implementing the vendor's latest release of G2®, and working to optimize the system's processing procedures.

We are currently projecting that for the balance of FY 1996 we will be adding approximately 900 discrettes and 500 analogs. This will bring TMACS up to a little over 3000 points (2090 analogs, 950 discrettes), which is still within our projected system capacity. We would expect the CPU utilization of the system, with this point count, one more serial port, one more remote terminal and 10 points/second (7 analog, 3 discrete) exceeding delta, to be approximately 29 CPU-%.

⁵Sun is a registered trademark of Sun Microsystems, Inc.

⁶UltraSPARC is a registered trademark of SPARC International, Inc., and licensed exclusively to Sun Microsystems, Inc.

⁷SPARCstation is a registered trademark of SPARC International, Inc., and licensed exclusively to Sun Microsystems, Inc.

2.0 TECHNICAL ANALYSIS

2.1 INTRODUCTION

A variety of measurements on the TMACS production and development systems provided the data to project CPU usage for various point configurations. This section describes how we conducted these measurements and presents the formulas we derived from the data to make our performance projections.

We conducted all tests using TMACS Release 9.1, with G2[®] Version 4.0, Revision 1, running under Sun[®] Solaris[®] 2.4. The production system is a Sun[®] SPARC20[®]/100 Mhz machine. The development system is a Sun Microsystems SPARC20[®]/75 Mhz, dual CPU workstation.

2.2 CPU UTILIZATION MEASUREMENTS

The CPU utilization measurements covered each of the functional processing areas that Section 1.0 describes: Background, I/O, Point, and Remote Telewindow[®] Processing. G2[®] procedures (software programs) generated the CPU utilization measurements. These procedures ran on the TMACS development system.

Automated G2[®] procedures, which are now part of TMACS, measured background and point processing CPU utilization. These procedures also compiled the results in tables for subsequent publication.

The Acromag bridge and Acromag emulation software generated I/O processing data. Output from the bridge programs went to the development system via the G2[®] vendor's GSI[™] interface package. This is the same arrangement the TMACS production system uses to interface to live data in the field.

Observations of the CPU utilization meters on the TMACS production system also provided measurements of remote Telewindow[®] processing. We compared data from these measurements to those from the development system to validate development system and calculated results.

2.2.1 Background Processing

The background processing procedure measured system background CPU utilization as a function of the number of analog and digital points in TMACS. Currently there are approximately 1600 points in TMACS. The target system is defined to have 10,000 points. Appendix C shows the results from these measurements, which includes a table for various point counts ranging from 1600 to 10,000.

⁸Solaris is a trademark of Sun Microsystems, Inc.

The following formula fits the measurement data:

$$\begin{aligned} \text{Background CPU Usage (CPU-\%)} = & 8.1 + \\ & 0.0024 * (\text{<No. of Analog Points>} - 1589) + \\ & 0.0026 * (\text{<No. of Discrete Points>} - 49) \end{aligned}$$

Example: For a configuration with 3000 analog points and 1000 discrete points, the CPU usage for just background processing would be as follows:

$$\begin{aligned} \text{Background CPU usage (CPU-\%)} = & 8.1 + 0.0024 * (3000 - 1589) \\ & + 0.0026 * (1000 - 49) \\ = & \underline{14 \text{ CPU-\%}} \end{aligned}$$

2.2.2 I/O Processing

The I/O processing procedure measured the CPU utilization necessary to support connection to I/O ports. The procedure used the Acromag bridge and simulated analog points. Appendix D shows the table for points versus number of ports. The CPU usage per I/O port was approximately 0.5 CPU-%.

The formulas we derived for determining CPU utilization for any number of I/O ports, at various data throughput rates are the following:

$$\text{I/O Processing CPU Usage @ 16 pts/sec (CPU-\%)} = 0.5 * \text{<No. of I/O Ports>}$$

$$\text{I/O Processing CPU Usage @ 32 pts/sec (CPU-\%)} = 1.2 * \text{<No. of I/O Ports>}$$

$$\text{I/O Processing CPU Usage @ 48 pts/sec (CPU-\%)} = 1.6 * \text{<No. of I/O Ports>}$$

$$\text{I/O Processing CPU Usage @ 64 pts/sec (CPU-\%)} = 2.7 * \text{<No. of I/O Ports>}$$

Example: For a configuration with 12 ports each with a data throughput of less than 16 points/sec, the CPU usage for just I/O processing would be as follows:

$$\text{I/O Processing CPU usage (CPU-\%)} = 0.5 * 12 = \underline{6 \text{ CPU-\%}}$$

2.2.3 Point Processing

The point processing procedures measured the CPU utilization required to process analog and digital points. The procedures also provided CPU utilization measurements of the functional components that make up point processing, which include the value update, delta check (analog only), alarm limit checks, rate-of-change check (analog only), and logging to disk. These measurements were for steady-state conditions, i.e., no point exceeded its alarm or rate-of-change limits. Appendices E and F show the results tables of these measurements. Note Appendix E refers to analog points as "Continuous" points.

The formula we derived for determining CPU utilization for any number of points, using the current TMACS software/hardware configuration is the following:

Point Processing CPU Usage (CPU-%) =

$$\begin{aligned} &0.27 * (\text{No. of Analog points/sec that } \underline{\text{do not}} \text{ exceed the delta limit}) + \\ &0.89 * (\text{No. of Analog points/sec that exceed the delta limit}) + \\ &0.77 * (\text{No. of Discrete points/sec that change state}) \end{aligned}$$

Example: For a configuration that processes 50 analog points/second that do not exceed the delta limit, 10 analog points/second that do exceed the delta limit, and 4 discrete points/second that change state, the CPU usage for just point processing would be as follows:

$$\begin{aligned} \text{Point Processing CPU Usage (CPU-\%)} &= (0.27 * 50) + (0.89 * 10) + (0.77 * 4) \\ &= \underline{26 \text{ CPU-\%}} \end{aligned}$$

2.2.4 Remote Telewindow® Processing

The remote Telewindow® processing procedure measured CPU utilization required to support remote operator terminals. This procedure ran on the TMACS development system. Appendix G gives the CPU utilization figures recorded when Telewindows® were in use and when they were not. The measurement method was to find the difference between the system's average CPU utilization with several remote windows connected and with no remote windows connected.

The formula we derived for determining CPU utilization for any number of Telewindows® processes, using the current TMACS software/hardware configuration, is the following:

Remote Telewindow® CPU Usage (CPU-%) =

$$0.6 * (\text{Number of Remote Telewindow® Terminals})$$

Example: For a configuration with 6 remote Telewindows® terminals, the CPU usage for all remote terminal processing would be as follows:

$$\text{Remote Telewindows® CPU usage (CPU-\%)} = 0.6 * 6 = \underline{3.6 \text{ CPU-\%}}$$

APPENDIX A - TMACS Release 9.1 Profile

TMACS Profile (as of 1/24/96):

Central Computers - 1
 Application Software - Gensym Corp. G2®, Release 4.0, Revision 1
 Current Release - TMACS, Release 9.1
 RTUs - 106 Acromag, Series 4300,
 1 Enraf Series 858 CIU
 System Start-Up - January 29, 1993

Tanks being Monitored: 109 out of 177 (not including K Basins)

AN-101, -102, -103, -104, -105, -106, -107
 BX-101, -102, -103, -105, -106, -107, -108, -109, -110, -111, -112
 BY-101, -103, -104, -105, -106, -107, -108, -110, -111, -112
 C -101, -102, -103, -104, -105, -106, -107, -108, -109, -110, -111, -112
 C -201, -202, -203
 S -101, -102, -103, -104, -105, -106, -107, -108, -109, -110, -111, -112
 SX-101, -102, -103, -104, -105, -106, -107, -108, -109, -110, -111, -112
 SX-113, -114
 SY-101, -102, -103
 T -101, -102, -103, -104, -106, -107, -108, -109, -110, -111, -112
 T -201, -202, -203, -204
 TX-118
 TY-101, -102, -103, -104, -105, -106
 U -101, -102, -103, -105, -106, -107, -108, -109, -110, -111, -112,
 U -201, -202, -203, -204

Systems Being Monitored:

100-K Basins (K East, K West) 3 discretes
 Standard Hydrogen Monitoring System (SHMS) 36 discretes

Instrumentation Being Monitored: 1570 sensors

Continuous Sensors: 1531
 Temperature sensors: 1350 (1,082 TCs, 62 RTDs, 206 ref TCs)
 Pressure sensors: 18
 Level sensors: 109 (23 ENRAFs, 86 via SACS)
 Hydrogen sensors: 34
 Flow sensors: 20

 Discrete Sensors: 39 (18 H₂, 18 Trouble, 3 K Basin)

APPENDIX B - Target System Profile**Target System Point Configuration**

ANALOG POINTS			
Polling Rate (seconds)	Number of Points Configured	Number of Points/Second (Polled by Bridges)	Number of Points/Second that Exceed Delta Limit
1	200	200	20
10	1,800	180	18
60	1,000	15	1.5
600	3,000	5	0.5
TOTALS	6,000	400	40

DISCRETE POINTS			
Polling Rate (seconds)	Number of Points Configured	Number of Points/Second (Polled by Bridges)	Number of Points/Second that Change State
1	250	250	4
10	3,750	375	6
TOTALS	4,000	625	10

APPENDIX C - Background CPU

Background CPU Utilization
versus
Number of Analog and Discrete Points in System

No. of Cont. Points	No. of Dscrt. Points		Average (10 Min.)	Minimum (10 Min.)	Maximum (10 Min.)	Std Dev (10 Min.)
1590	50	BKGD	8.138	6.206	11.523	9.2%
2000	50	BKGD	9.107	7.324	10.42	7.9%
2000	2000	BKGD	13.949	11.867	15.5	4.8%
3000	2000	BKGD	16.432	14.106	28.547	8.8%
3000	3000	BKGD	18.908	16.801	21.667	3.7%
4000	3000	BKGD	21.292	19.513	24.105	3.4%
4000	4000	BKGD	23.711	22.064	25.754	2.7%
5000	4000	BKGD	26.587	24.775	28.909	2.4%
5000	5000	BKGD	28.855	26.73	47.511	7.5%
Pts/Sec	20	from - to	kb/cnt-pt	bkgd/con-pt	kb/dsc-pt	bkgd/dsc-pt
Delta	0.0	2000-3000	9.5	0.0025	11.3	0.0025
Pt. Proc.	True	3000-4000	22.1	0.0024	12.2	0.0024
Alarm Proc.	True	4000-5000	19.7	0.0029	14.5	0.0023
ROC Proc.	True					
Log Proc.	True	Average	17.1	0.0026	12.7	0.0024

APPENDIX D - I/O Processing

CPU Utilization
for
I/O Processing Functions
with
Analog Points

# of Ports	16 Points/Second	32 Points/Second	48 Points/Second	64 Points/second
0	8.3	8.3	8.3	8.3
1	9.1	9.5	9.9	10.1
2	9.8	10.5	11.8	11.2
3	10.0	11.7	13.0	12.8
4	10.5	13.0	14.8	14.6
LINEAR SLOPE	0.5	1.2	1.6	2.7

APPENDIX E - Point Processing of Analogs

CPU Utilization
for
Point Processing Functions
with
Analog Points

Pt. Proc. Function		Average (10 Min.)	Minimum (10 Min.)	Maximum (10 Min.)	Std Dev (10 Min.)
All Funcs	% CPU	27.038	25.26	31.994	2.73%
w/o Logging	% CPU	16.595	14.715	17.723	3.33%
w/o ROC	% CPU	15.215	12.842	16.86	4.40%
w/o Alarm	% CPU	14.723	12.929	16.543	4.33%
< Delta	% CPU	12.683	11.079	16.759	5.19%
w/o Pt Proc	% CPU	9.185	7.17	14.912	8.93%
w/o Rule	% CPU	8.867	7.155	9.952	6.00%
BKGD	% CPU	8.221	6.79	12.292	6.98%
Summary Breakdown	% CPU		Pt. Proc. Breakdown	%cpu/pt/sec	
Pt Proc	17.85	66.0%	Update Pt.	0.17	19.6%
Rule Proc	0.32	1.2%	Delta Check	0.10	11.4%
I/O Proc	0.65	2.4%	Alarm Chk	0.02	2.8%
Bkgd	8.22	30.4%	ROC Check	0.07	7.7%
			Log to Disk	0.52	58.5%
Total:	27.04	100.0%	Total:	0.89	100.0%
Pts/sec:	20	# Cont Pts:	1589	# Dscrt Pts:	49

APPENDIX F - Point Processing of Discretes

CPU Utilization
for
Point Processing Functions
with
Discrete Points

Pt. Proc. Function		Average (10 Min.)	Minimum (10 Min.)	Maximum (10 Min.)	Std Dev (10 Min.)
All Funcs	% CPU	25.026	23.511	28.509	2.85%
w/o Logging	% CPU	14.682	13.226	15.788	4.15%
w/o Alarm	% CPU	14.221	12.543	20.312	5.63%
w/o Pt Proc	% CPU	9.63	7.424	10.883	7.11%
w/o Rule	% CPU	8.18	6.342	16.622	11.91%
BKGD	% CPU	8.042	6.474	9.268	6.64%
Summary Breakdown	% CPU		Pt. Proc. Breakdown	%cpu/pt/sec	
Pt Proc	15.40	61.5%	Update Pt.	0.23	29.8%
Rule Proc	1.45	5.8%	Alarm Chk	0.02	3.0%
I/O Proc	0.14	0.6%	Log to Disk	0.52	67.2%
Bkgd	8.04	32.1%			
Total:	25.03	100.0%	Total:	0.77	100.0%
Pts/sec:	20	# Cont Pts:	1589	# Dscrt Pts:	49

APPENDIX G - Remote Window Processing

CPU Utilization
for
Remote Telewindow® Processing Functions

Measurements were on a SPARC-20/75 Mhz system on TCP/IP network

REMOTE TELEWINDOW® PROCESSING			
Description	Average CPU-%	Minimum CPU-%	Maximum CPU-%
2 Windows	9.2	6.8	0.11
0 Windows	8.0	6.1	0.10
DIFFERENCE	1.2		

From this we compute the Average CPU usage to be 0.6 CPU-% per Telewindow®.

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