598437
16p.

National Aeronautics and
Space Administration

John F. Kennedy Space Center

SPACEPORT
ENGINEERING AND
TECHNOLOGY

NASA ADVANCED SENSORS SYMPOSIUM

VALVE HEALTH MONITOR (VHM)

Smart Current Signature Sensor

Jose M Perotti, Sensor Group Lead

Command, Monitoring and Control Branch
Spaceport Engineering &Technology Directorate,
Kennedy Space Center, Florida

Why Valve Health Monitor ?

NASA Requirements

- Reduce system's processing/operational costs.
- Increase system's reliability and lower maintainability costs.
- Provide continuous system's health status, detecting and ultimately predicting system's failures before it happens.
- Do not increase system's probability of failure - Operate independently and autonomously from monitored system.
- Minimize human intervention.

Project Objective

Develop a sensor with following characteristics:

- Non-invasive (do not add to system failure probability)
- Embed system and sensor health knowledge in sensor.
- Internally, independently and autonomously perform sensor and system and sensor health checks.

Valve Health Monitor – Target Valve

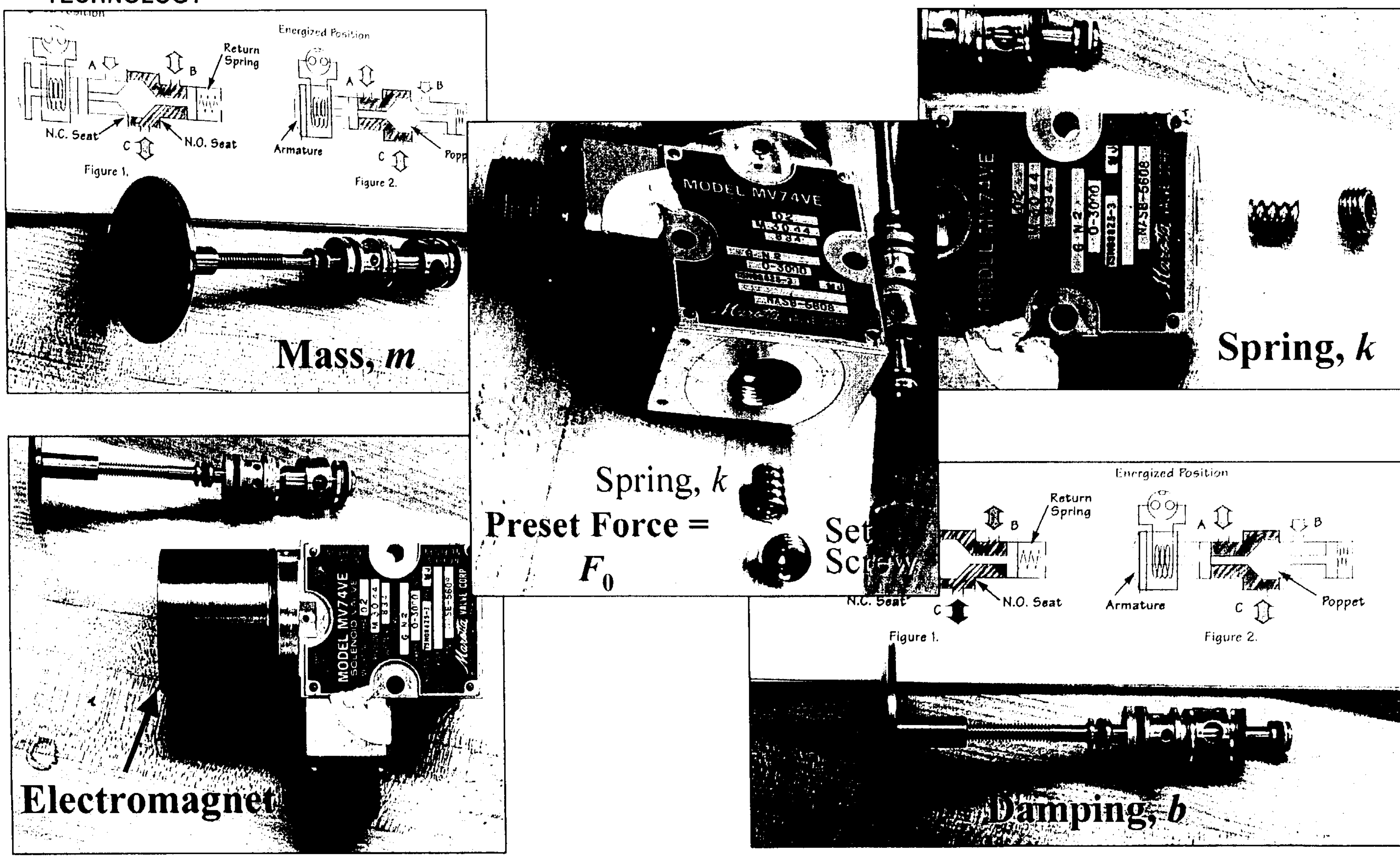
- Selected valve for this project was MAROTTA MV74.
- Currently widely used at both Launch Pads at KSC.
- Valve's solenoid operates at 24 Vdc and 1 Amp. approximately.
- Turn-on time for valve is typically 30 msec (20-40 msec range).
- Turn-off time for valve is typically 5 msec (2-10 msec range).

National Aeronautics and
Space Administration

John F. Kennedy Space Center

Valve Health Monitor – Target Valve

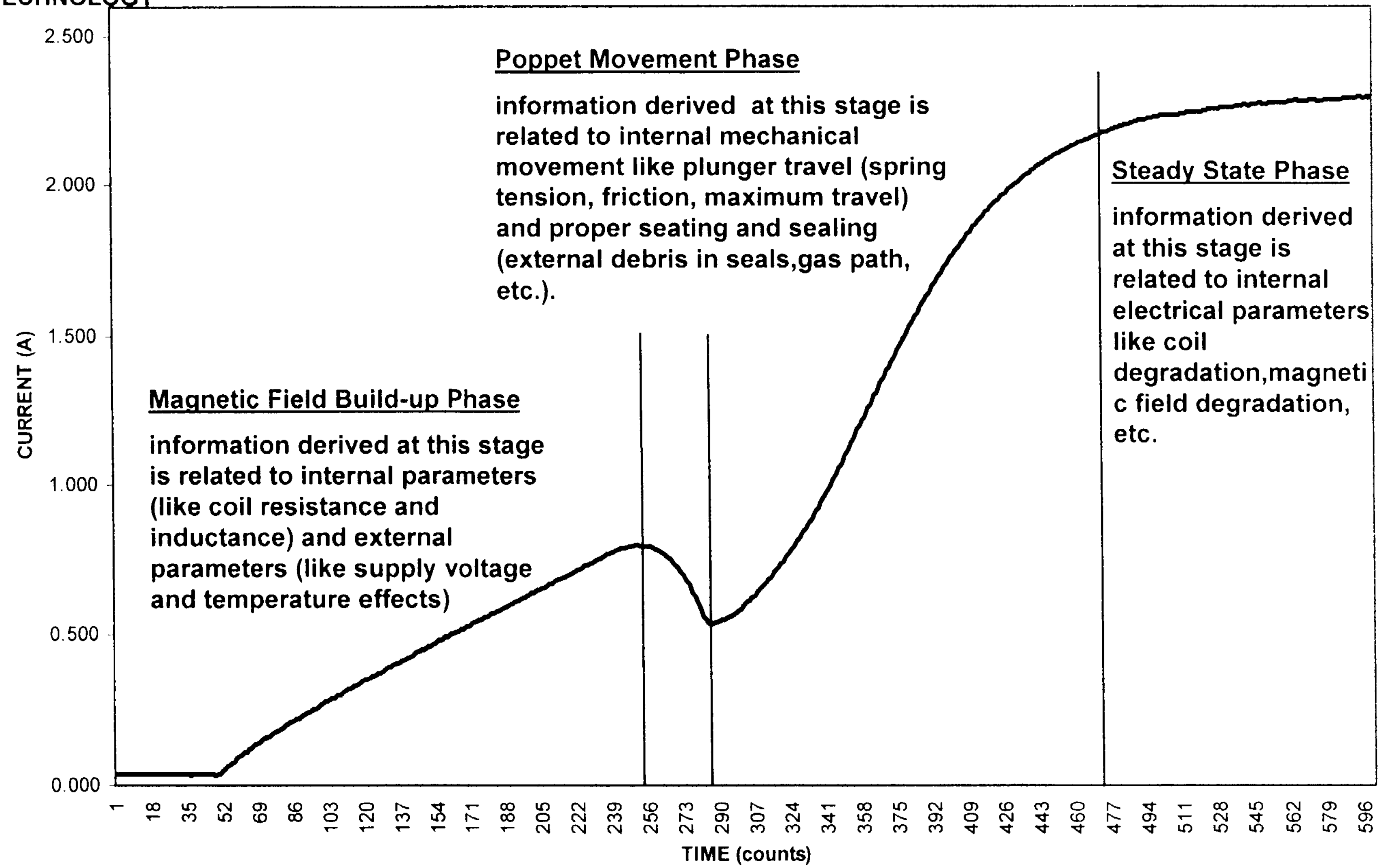
SPACEPORT
ENGINEERING AND
TECHNOLOGY



Why Current Signature?

SPACEPORT ENGINEERING AND TECHNOLOGY

TIMING CHART FOR VALVE TURN-ON CYCLE

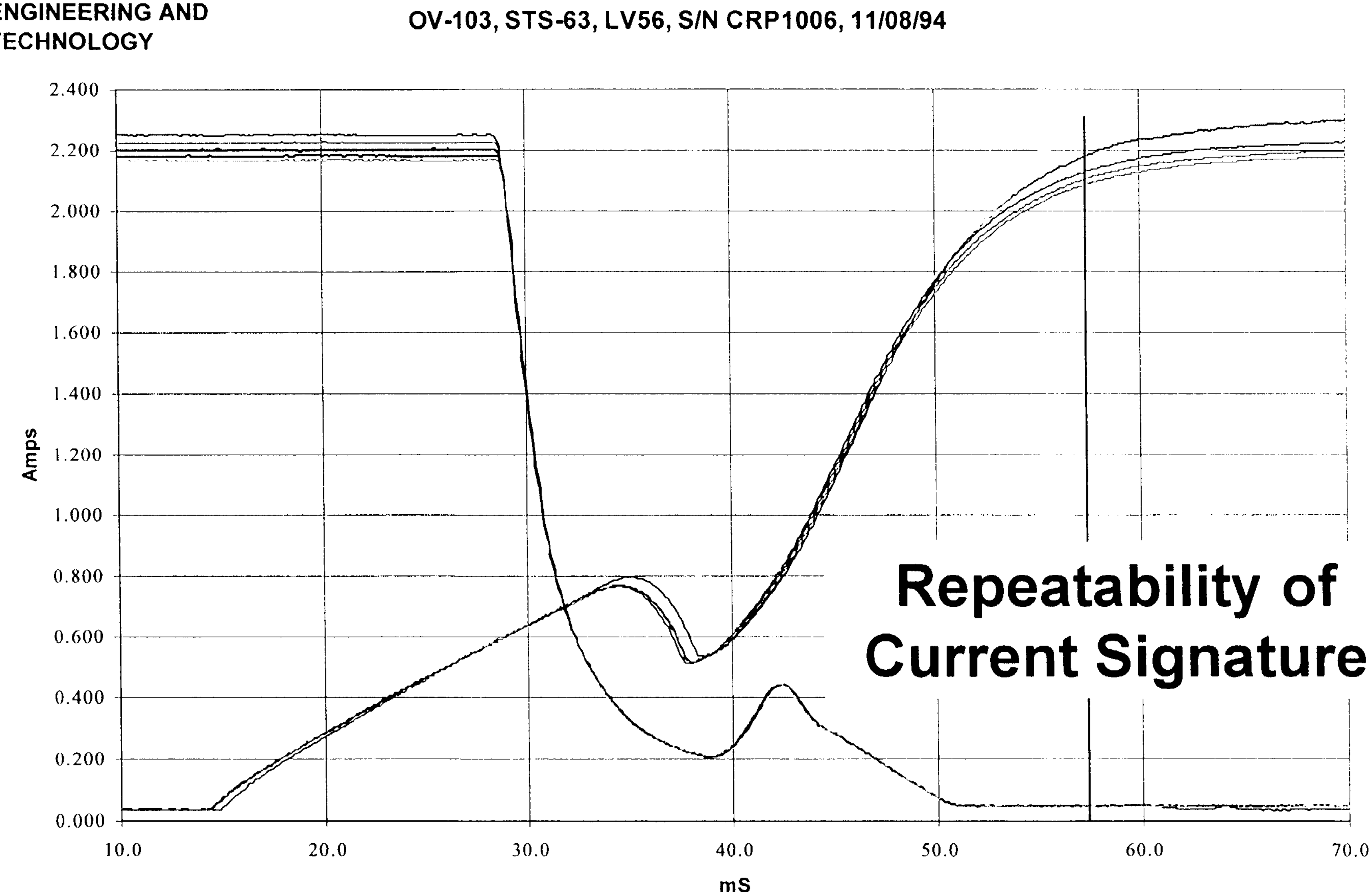


National Aeronautics and
Space Administration

John F. Kennedy Space Center

Similar Current Signatures to MV74

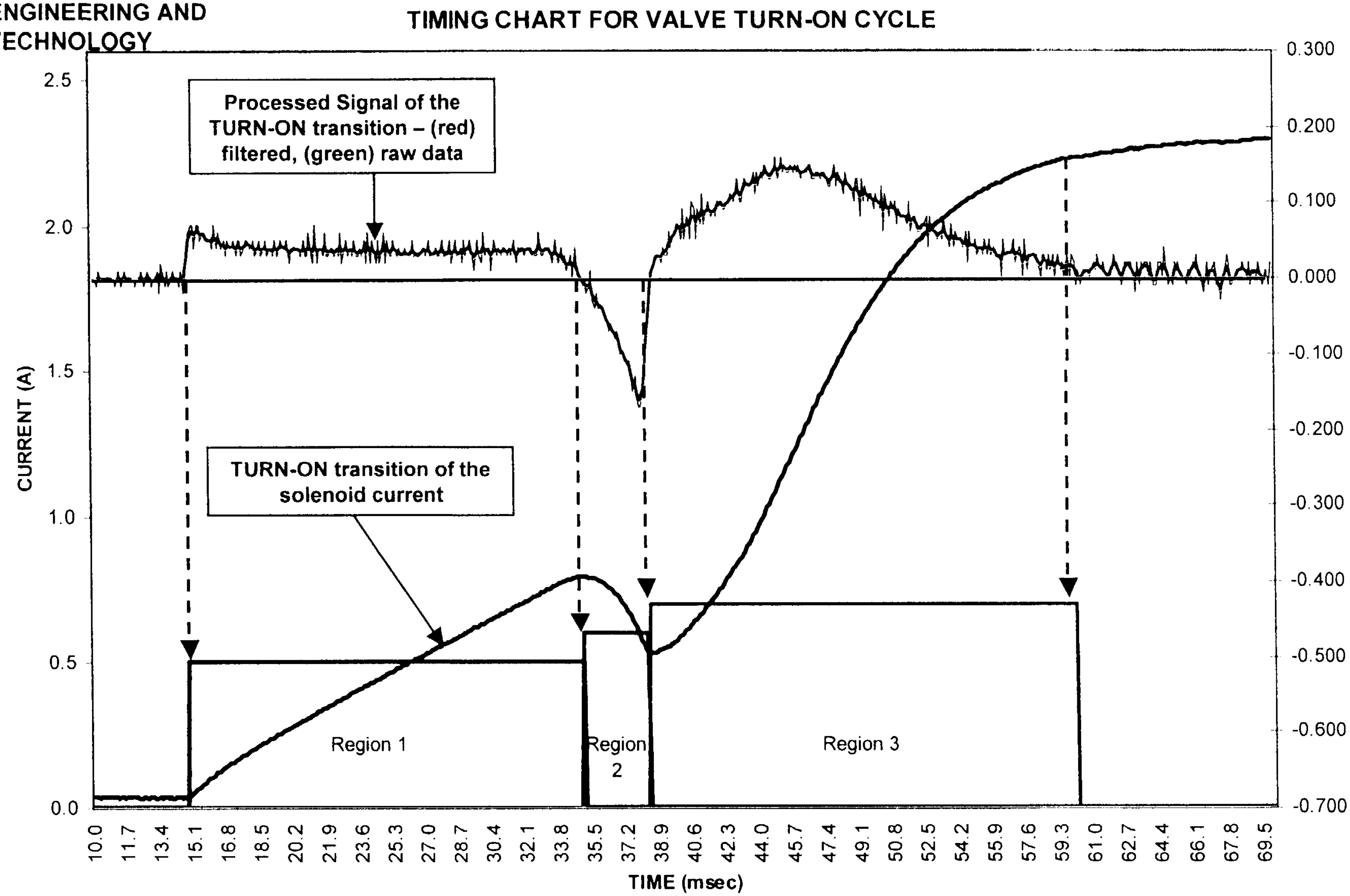
SPACEPORT
ENGINEERING AND
TECHNOLOGY



Repeatability of Current Signature

Why Current Signature?

SPACEPORT
ENGINEERING AND
TECHNOLOGY

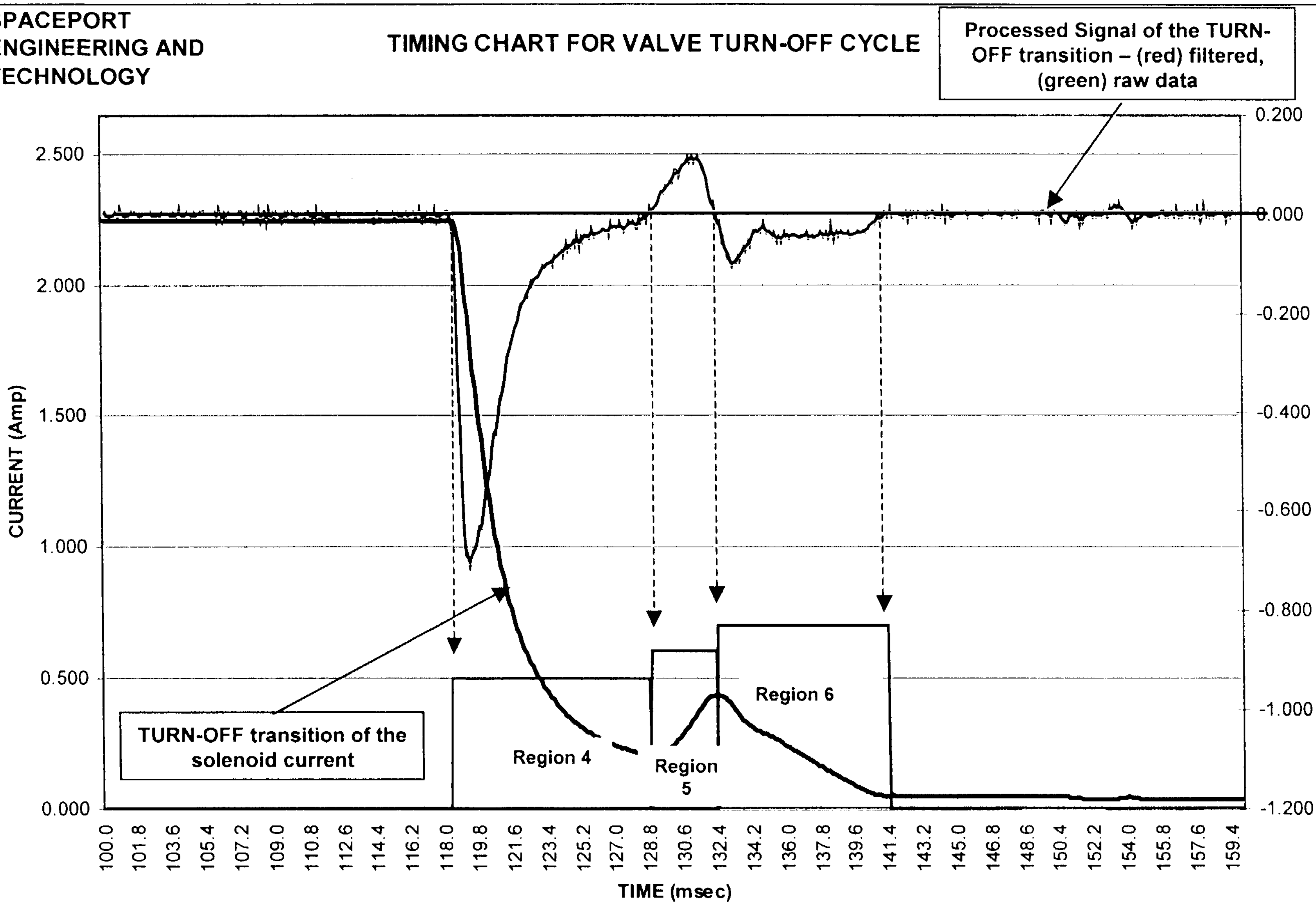


National Aeronautics and
Space Administration

John F. Kennedy Space Center

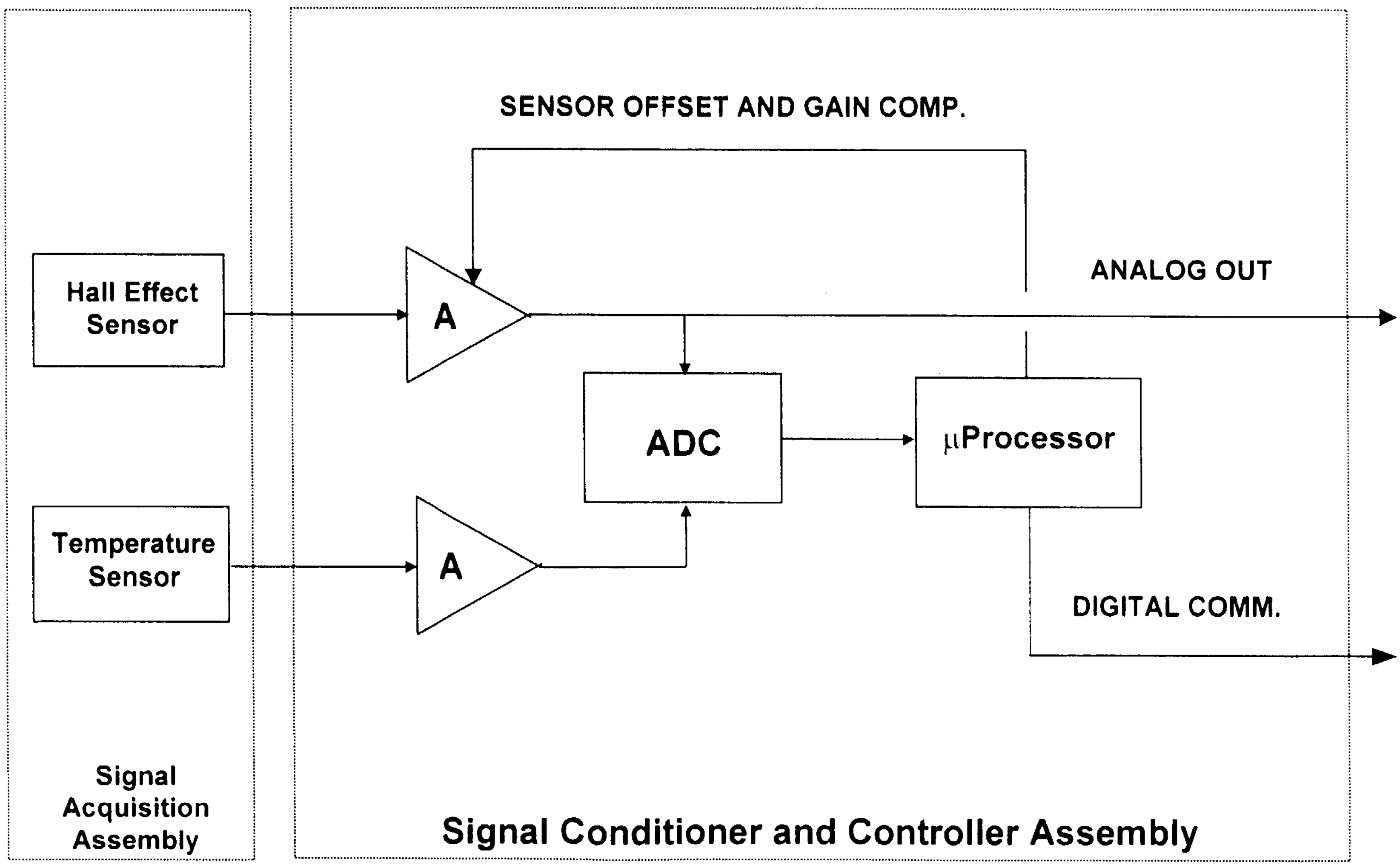
Why Current Signature?

SPACEPORT ENGINEERING AND TECHNOLOGY

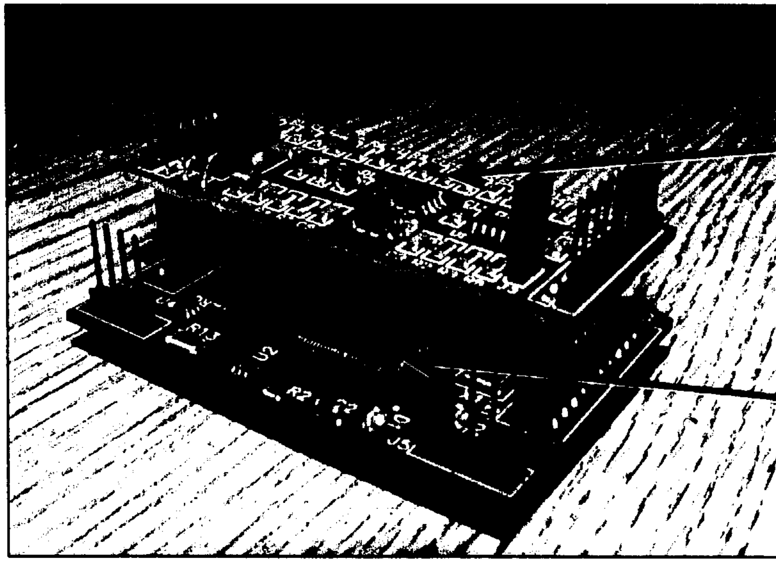


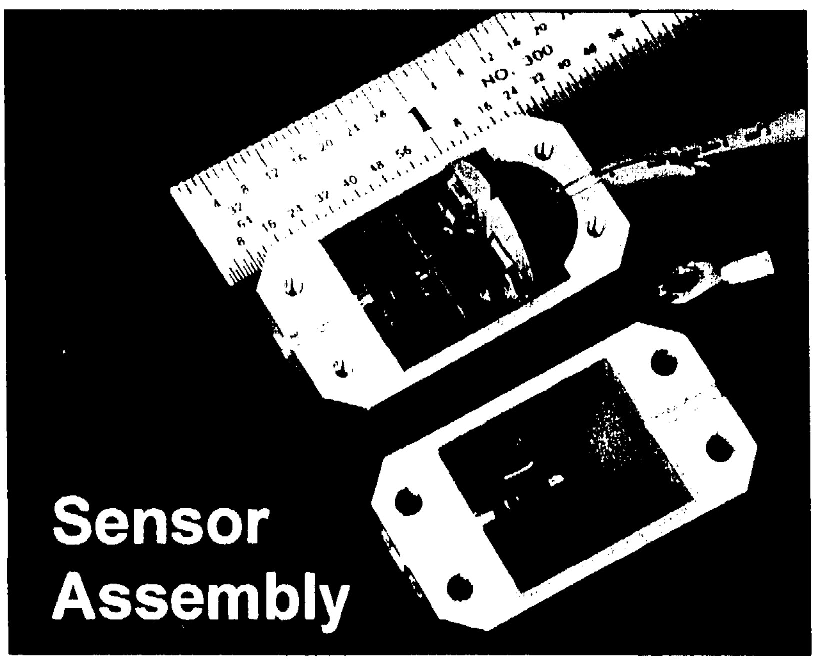
VHM Design Approach

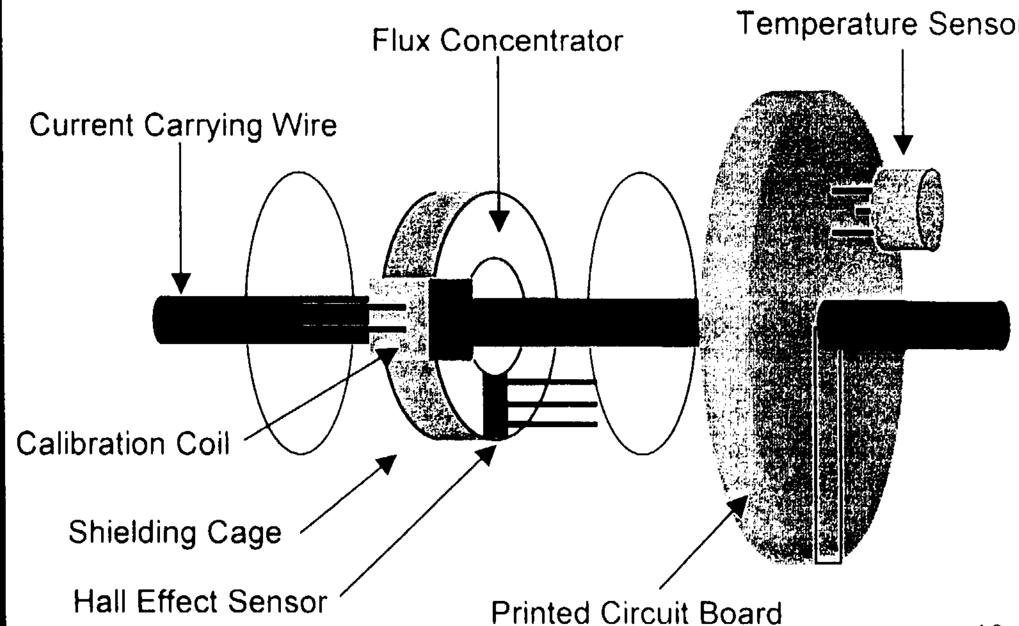
SPACEPORT
ENGINEERING AND
TECHNOLOGY



VHM Design Approach







VHM Design Approach

Algorithm for Valve Health Monitor

Learning Phase

a. Process good valve N cycles to acquired the valve's nominal profile.
b. Measure the desired parameters for each region.
c. Calculate the representative values for each parameter.
d. Calculate their tolerances.

Operational Phase

1) Information Monitoring Mode

a. Count the total number of times the valve is cycled.
b. Measure the desired parameters for each region.
c. Verify that the measured values agree with the nominal values with in the specified tolerance.
d. Count/Record the number of times any "out of tolerance" is detected.
e. Report it as an anomalous cycle as well as the failed parameter.
f. Count the total number of anomalous cycles.

VHM Design Approach

Algorithm for Valve Health Monitor (Continuation)

2) Information Reporting Mode
   a. Remain in Monitoring Mode until user requests data, switch to transfer mode.
   b. Output: Total Number of cycles
   c. Output total number of anomalous cycles
   d. Report which parameters were out of tolerance.

3) Analyze, Store, Display Mode (User Interface)
   a. This is a program which reads the parameter data from the processor module
   b. Stores on the hard-drive, and displays on the monitor
   c. Analyze which anomalous parameters correspond to physical failures, anomalies, changes or degradation of the valve. Start with known failures to build up the knowledge base of how the valves behave under anomalous / failure conditions.

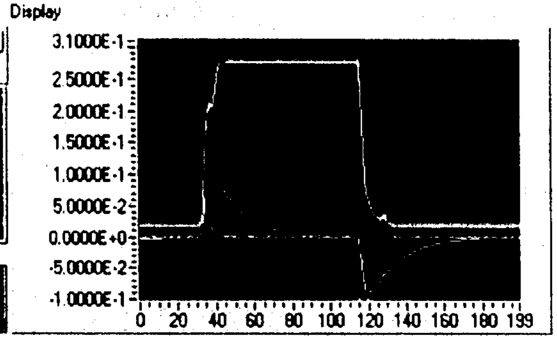
National Aeronautics and
Space Administration

John F. Kennedy Space Center

VHM Design Approach

SP/
EN(
TE(

Display



Current Signature

Valve Control Source: Program

Data Source: Live Data

% Error: 0.000000

Valve state: OFF

Applied Volts: 32.0000

Valve: 0

Solenoid Temperature: 20.7000

ms per loop: 28280

ms per point: 1.2283

Next cycle: ON

Wait for User: OFF

Number of Cycles: 2

Valve State: Low

Rising Edge Parameters

Num R Params: 6 | R STD Scale: 3.00

[redacted]

	Measured	Nominal	Tolerance	Error
1st Peak	2.570E+1	1.786E+1	2.448E+1	7.841E+0
1st Valley	2.426E+1	1.689E+1	2.298E+1	7.365E+0
1st High	3.332E+1	2.293E+1	3.240E+1	1.040E+1
2nd High	3.332E+1	2.292E+1	3.241E+1	1.040E+1
	3.335E+1	2.295E+1	3.242E+1	1.040E+1
	3.333E+1	2.294E+1	3.242E+1	1.039E+1

[redacted]

	Measured	Nominal	Tolerance	Error
1st Peak	77.00	61.67	47.88	15.33
1st Valley	97.00	77.67	60.37	19.33
1st High	261.00	179.33	207.31	81.67
2nd High	273.00	198.33	185.77	74.67
	323.00	240.33	201.68	82.67
	342.00	254.00	203.68	88.00

[redacted]

	Measured	Nominal	Tolerance	Error
1st Peak	1.782E-1	1.604E-1	1.830E-1	1.783E-2
1st Valley	-7.145E-2	-4.800E-2	7.405E-2	-2.346E-2
1st High	5.522E-2	4.178E-2	6.477E-2	1.344E-2
2nd High	-2.498E-4	-3.093E-4	2.528E-4	5.949E-5
	5.651E-4	7.456E-4	3.254E-4	-1.805E-4
	-7.298E-4	-4.605E-4	6.102E-4	-2.693E-4

Falling Edge Parameters

Num F Params: 8 | F STD Scale: 3.00

	Measured	Nominal	Tolerance	Error
1st Valley	3.184E+0	3.170E+0	6.074E-2	1.333E-2
1st Peak	3.990E+0	3.961E+0	6.912E-2	2.855E-2
2nd Vally	2.118E+0	2.121E+0	2.573E-2	-2.854E-3
2nd Peak	2.237E+0	2.244E+0	1.254E-2	-7.206E-3
1st Low	2.233E+0	2.238E+0	9.397E-3	-5.402E-3
2nd Low	2.256E+0	2.246E+0	1.749E-2	1.008E-2

	Measured	Nominal	Tolerance	Error
1st Valley	195.00	196.00	3.12	-1.00
1st Peak	224.00	225.00	3.12	-1.00
2nd Valley	297.00	299.00	3.87	-2.00
2nd Peak	328.00	339.33	22.21	-11.33
1st Low	342.00	356.00	25.22	-14.00
2nd Low	386.00	372.00	24.80	14.00

	Measured	Nominal	Tolerance	Error
1st Valley	-1.457E-1	-1.450E-1	1.834E-3	-6.980E-4
1st Peak	2.751E-2	2.707E-2	8.708E-4	4.369E-4
2nd Valley	-2.555E-2	-2.481E-2	1.429E-3	-7.352E-4
2nd Peak	3.792E-3	3.128E-3	1.173E-3	6.640E-4
1st Low	-2.380E-4	-3.078E-4	1.289E-4	6.978E-5
2nd Low	5.280E-4	1.983E-4	5.713E-4	3.297E-4

G R P Count: 0

G F P Count: 0

VHM Design Approach

SP
EN
TE

Valve Control Source: Program

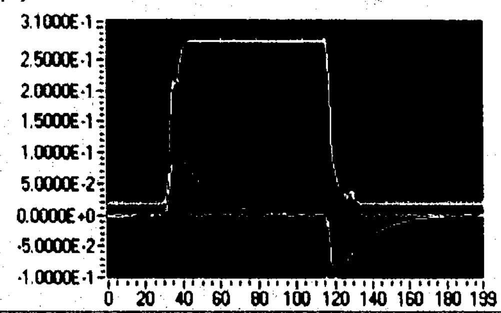
Data Source: Live Data

% Error: 0.000000

Current Signature

Operational Mode

Display



ms per loop: 1180532
ms per point: 1.2469

Valve state: OFF

Valve: 0

Applied Volts: 32.0000

Solenoid Temperature: 20.7000

Next cycle: ON

Wait for User: ON

Number of Cycles: 10

Valve State

Rising Edge Parameters

Num R Params: 6   R STD Scale: 3.00

	Measured	Nominal	Tolerance	Error
1st Peak	2.589E+1	2.308E+1	1.727E+1	2.809E+0
1st Valley	2.442E+1	2.179E+1	1.622E+1	2.631E+0
1st High	3.366E+1	2.987E+1	2.290E+1	3.794E+0
2nd High	3.363E+1	2.986E+1	2.291E+1	3.769E+0
	3.363E+1	2.988E+1	2.289E+1	3.753E+0
	3.362E+1	2.987E+1	2.290E+1	3.743E+0

1st Peak	76.00	71.67	33.55	4.33
1st Valley	96.00	90.22	42.25	5.78
1st High	258.00	228.44	155.90	29.56
2nd High	283.00	244.44	145.43	38.56
	301.00	273.33	147.16	27.67
	329.00	296.67	157.28	32.33

1st Peak	2.668E-1	2.230E-1	1.641E-1	4.377E-2
1st Valley	-7.297E-2	-6.409E-2	5.266E-2	-8.883E-3
1st High	5.701E-2	5.311E-2	4.577E-2	3.908E-3
2nd High	-1.362E-3	-4.106E-4	8.823E-4	-9.509E-4
	1.978E-4	4.941E-4	1.105E-3	-2.963E-4
	-6.120E-4	-3.680E-4	1.783E-3	-2.439E-4

Falling Edge Parameters

Num F Params: 6   F STD Scale: 3.00

	Measured	Nominal	Tolerance	Error
1st Valley	3.293E+0	3.183E+0	6.072E-2	1.097E-1
1st Peak	4.117E+0	3.966E+0	8.029E-2	1.503E-1
2nd Vally	2.179E+0	2.142E+0	5.520E-2	3.691E-2
2nd Peak	2.244E+0	2.247E+0	4.504E-2	-3.054E-3
1st Low	2.228E+0	2.238E+0	5.170E-2	-1.023E-2
2nd Low	2.236E+0	2.246E+0	4.800E-2	-9.974E-3

1st Valley	190.00	195.22	3.33	-5.22
1st Peak	219.00	224.11	3.72	-5.11
2nd Valley	297.00	298.22	3.10	-1.22
2nd Peak	325.00	340.89	30.18	-15.89
1st Low	344.00	357.78	35.96	-13.78
2nd Low	361.00	375.56	32.97	-14.56

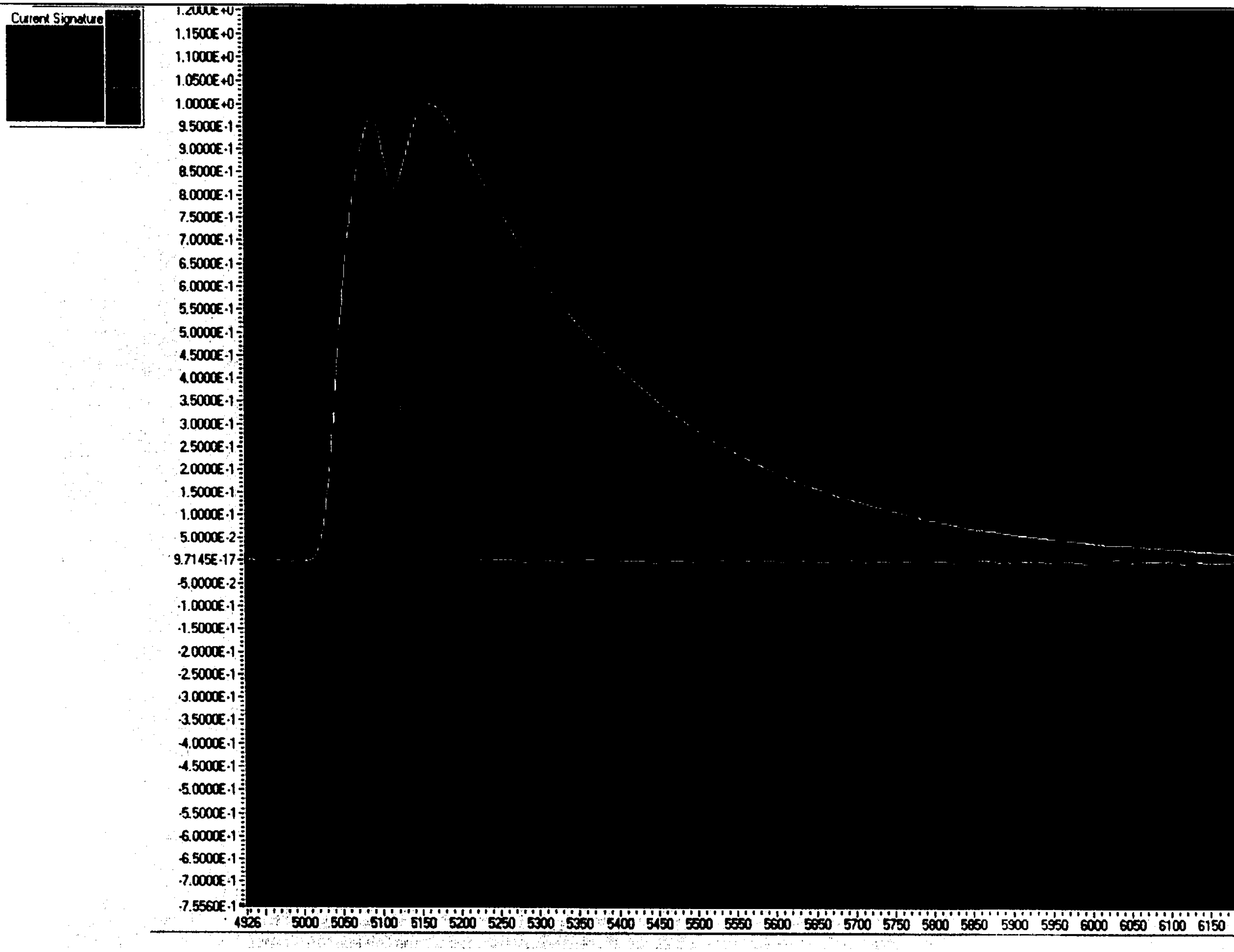
1st Valley	-1.453E-1	-1.391E-1	1.914E-2	-6.193E-3
1st Peak	2.826E-2	2.693E-2	2.029E-3	1.331E-3
2nd Valley	-2.480E-2	-2.456E-2	1.008E-3	-2.434E-4
2nd Peak	2.296E-3	2.538E-3	1.594E-3	-2.422E-4
1st Low	-8.402E-4	-4.988E-4	6.590E-4	-3.413E-4
2nd Low	4.888E-4	3.493E-4	6.359E-4	1.395E-4

G R P Count: 0

G F P Count: 0

VHM Design Approach

SF
EN
TE



VHM STATUS/CONCLUSIONS

Status

- Prototype of Current signature sensor (analog, digital, and power modules) has been designed, fabricated, and preliminary testing has been performed.
- Preliminary smart software algorithms to detect failure under different external conditions has been developed and is being tested at the present time.

Conclusions

- Sensor feasibility and functionality has been demonstrated.
- Prototypes have been fabricated and tested.
- Preliminary smart software algorithms have been developed and tested with preliminary good results.