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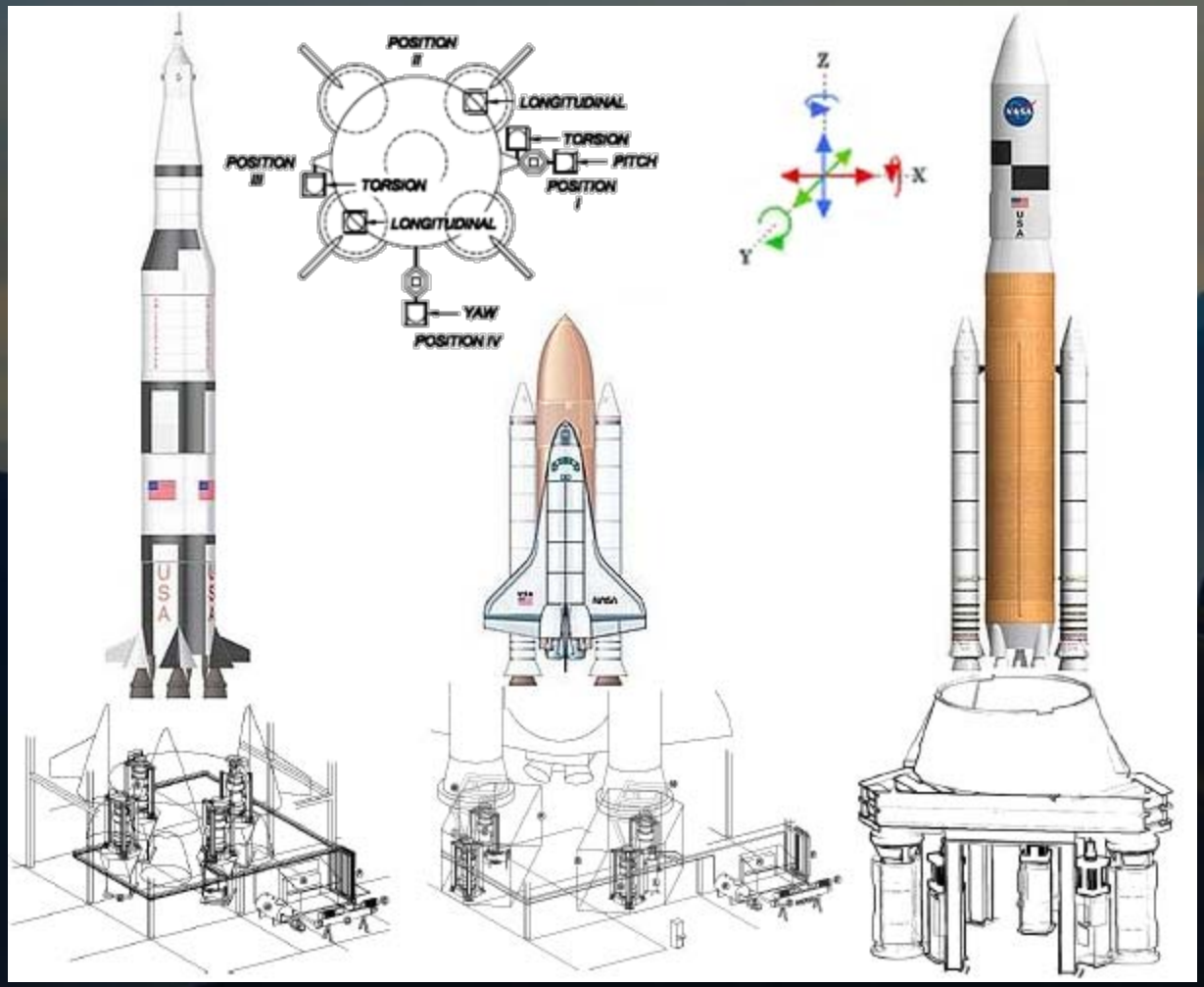
Hydrodynamic Suspension System (HDS)

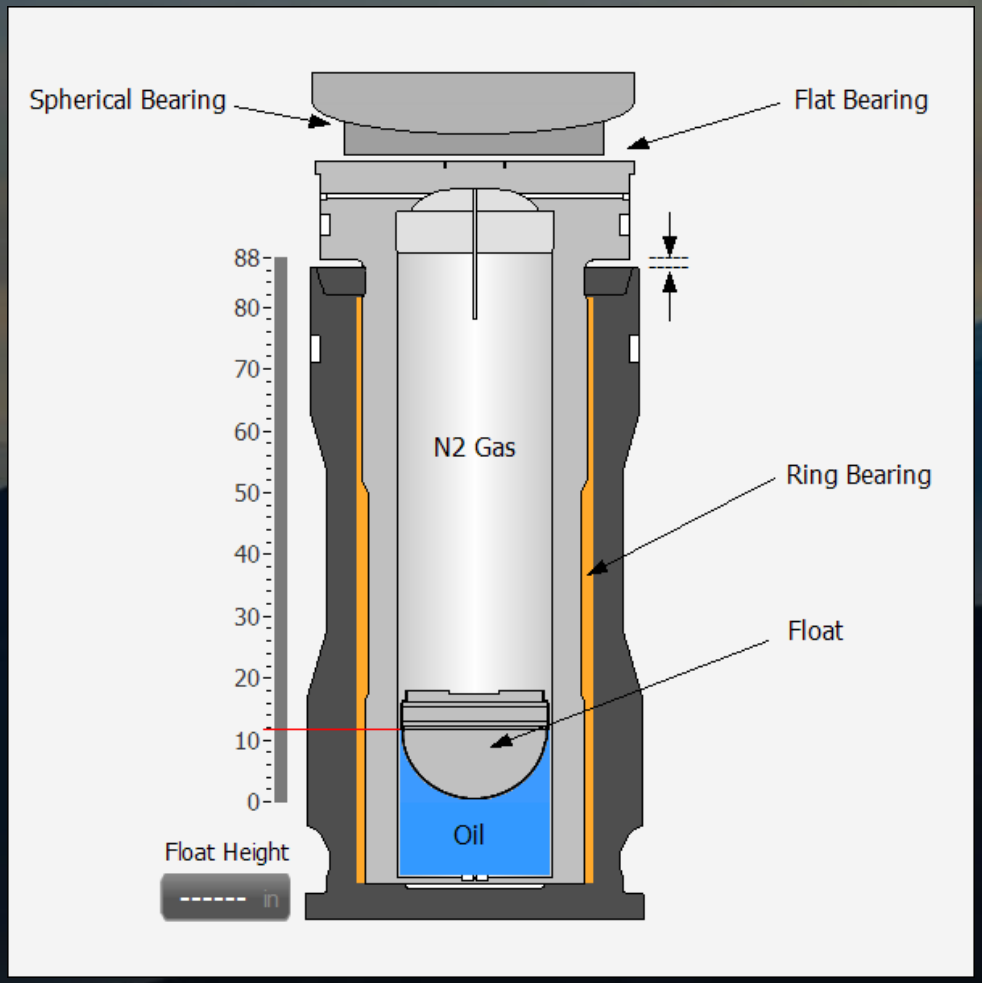
Integral part of IVGVT allowing meas. of vehicle modal characteristics
Verification of FEM, improve GN&C stability, identify resonance anomalies



7,200,000 lb Lifting cap. 6 Axis DOF to simulate Free-Free boundary flight conditions. Strategically placed electro-dynamic shakers simulate thrust oscillation and acoustic shock.

HDS Piston and Cylinder

Hydrodynamic Suspension System

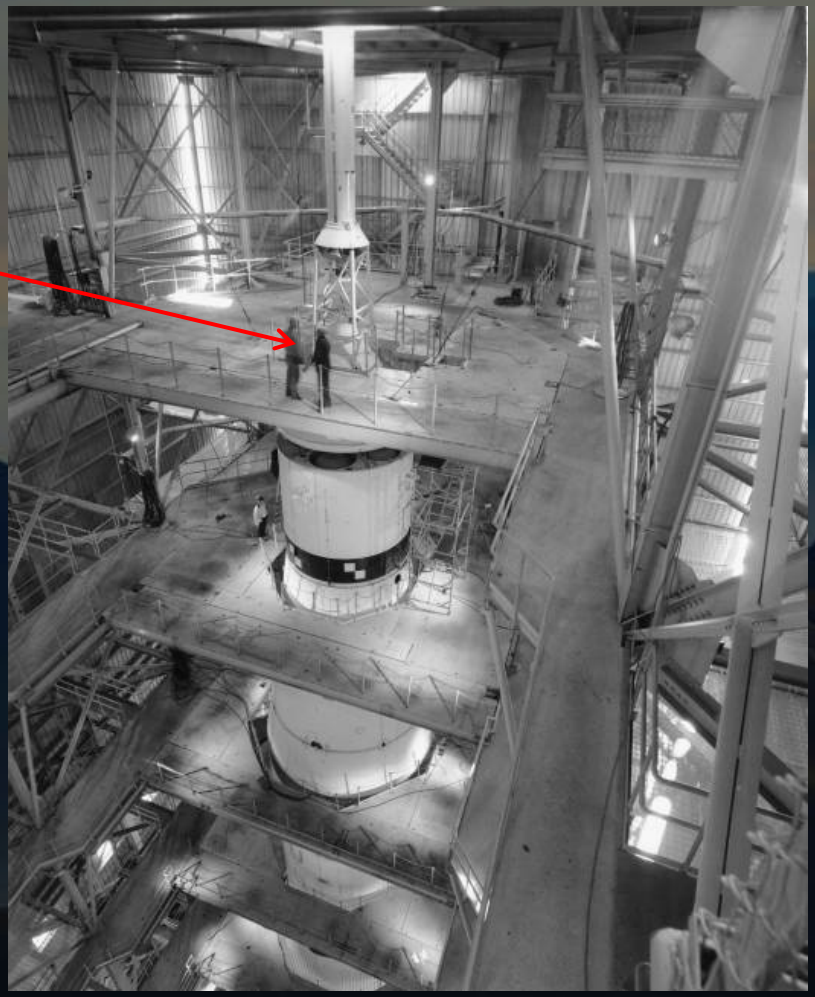


Unique Design: Hydraulic Lift + N2 Gas Spring. Nearly 100% inefficient but 100% effective! Why? Continuous Hydraulic flow through and across bearing surfaces.

Dynamic Test Stand, circa 1966

Saturn V Testing

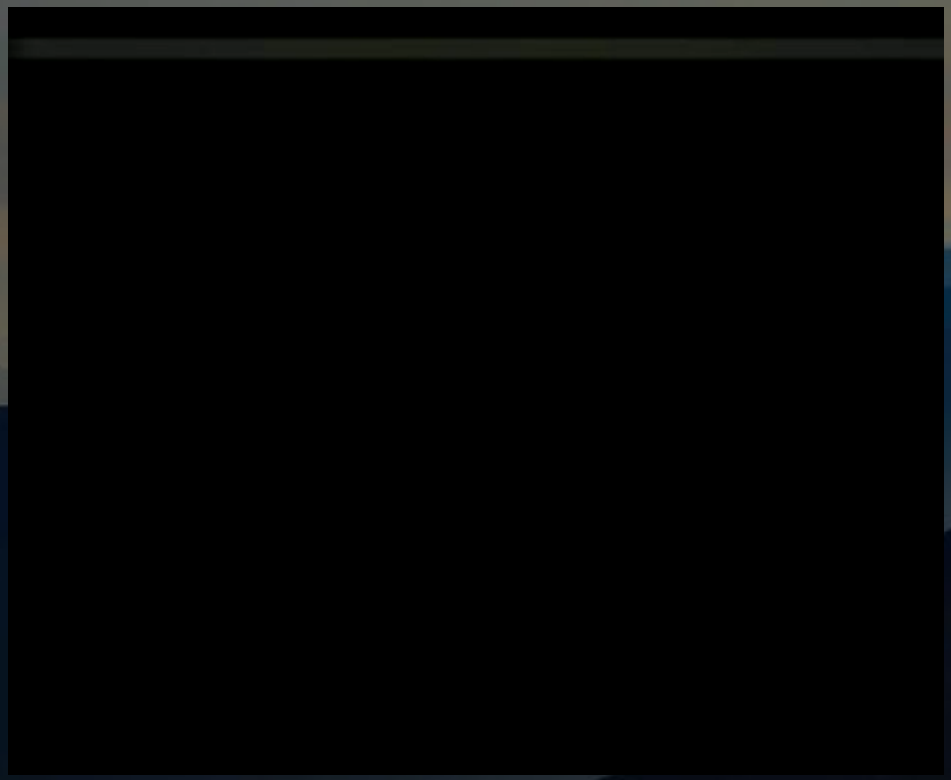
Once the HDS holds the launch vehicle in suspension, it will be so "weightless" that a person will be able to move it in any sideways direction with one hand



Prior to the HDS, IVGVT was accomplished by suspending the vehicle with cables. Prohibitive due to weight limitations and cable resonance.

Original HDS testing, circa 1965

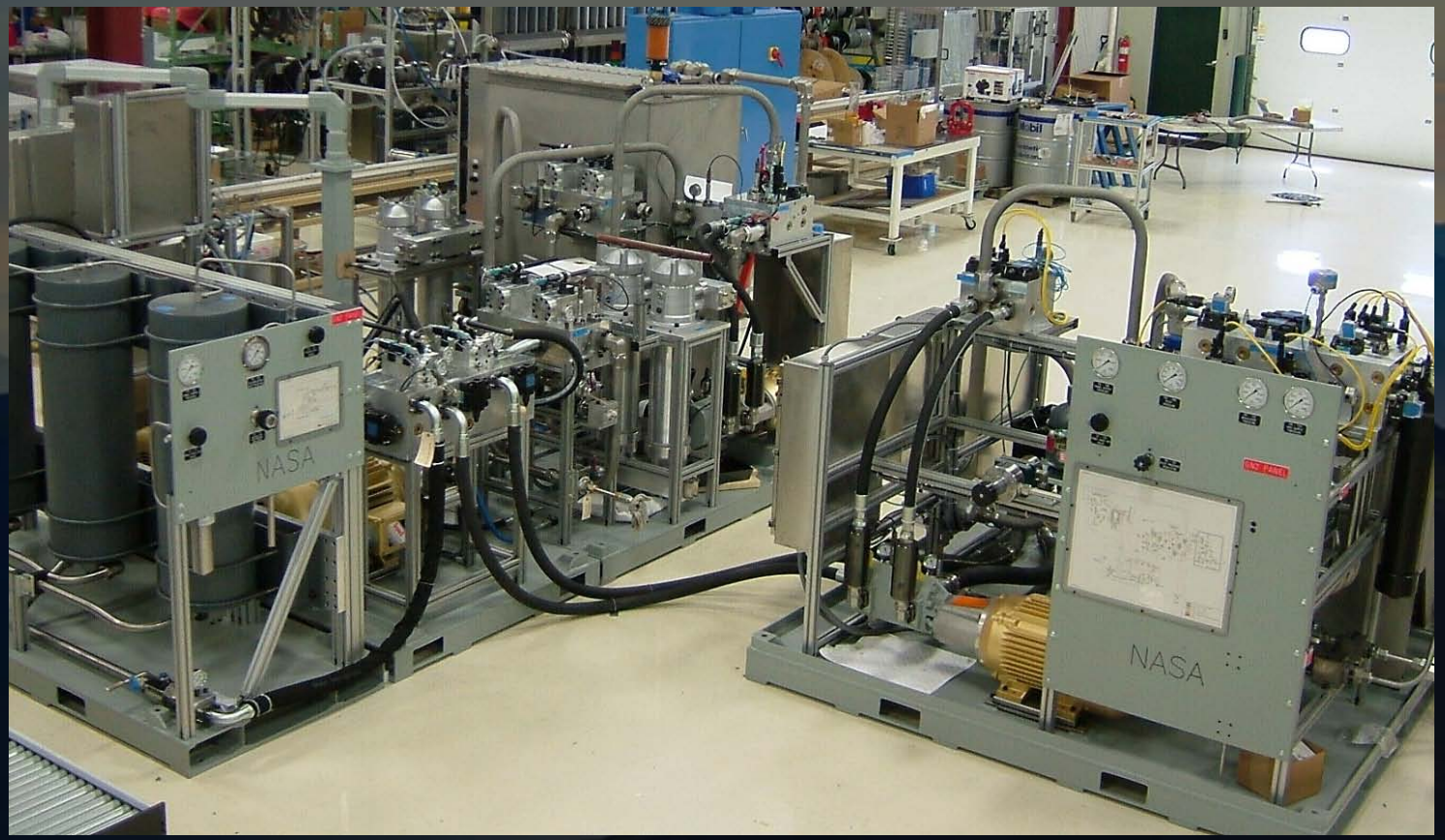
Martin Marietta Engineers



I wonder what a day around hydraulic oil does to a white shirt and tie?

Hydraulic Pump Unit and Sump Valve Stand

Hydrodynamic Suspension System



Interface to wide variety of analog and digital controls and sensors

Motor Controls (4), Discrete Valves (24), Proportional Valves (10), Pressure (20), Temp (9), Flow (3), Discrete Inputs (45), RTD (3), Discrete Outputs (14)

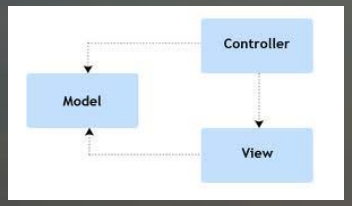
Refurbished HDS Cylinder and Piston

Hydrodynamic Suspension System

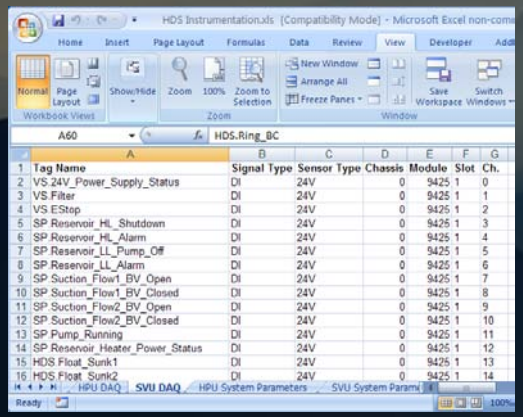
One year to refurbish 4 HDS, replacement cost > $1,000,000

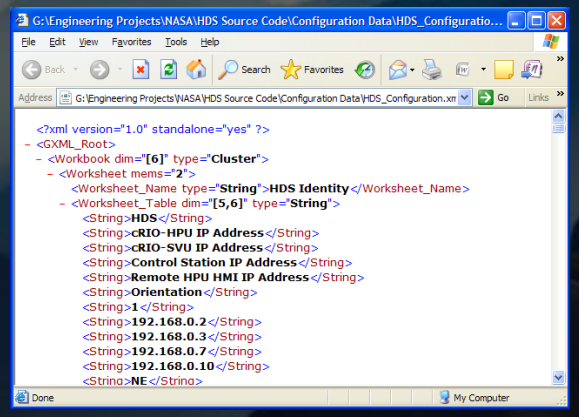
Design Goals:

1. Extensible Architecture supporting Distributed RT control



2. Workbook based Configuration (GXML based)

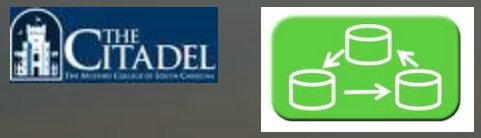




3. Instrumentation Management Tools
   a. Tag Properties: Scaling, Filtering, ZOFS, Initial Value, DB%
   b. Target Imaging
   c. HMI bindings

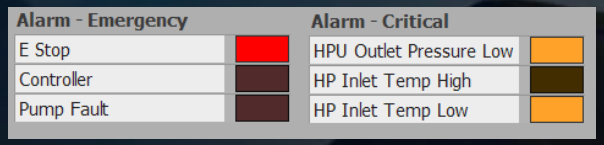
Design Goals:

4. 24/7 Historical Data Logging (up to 20Hz)



5. RT Target sync to GPS, timestamped +/- 1ms

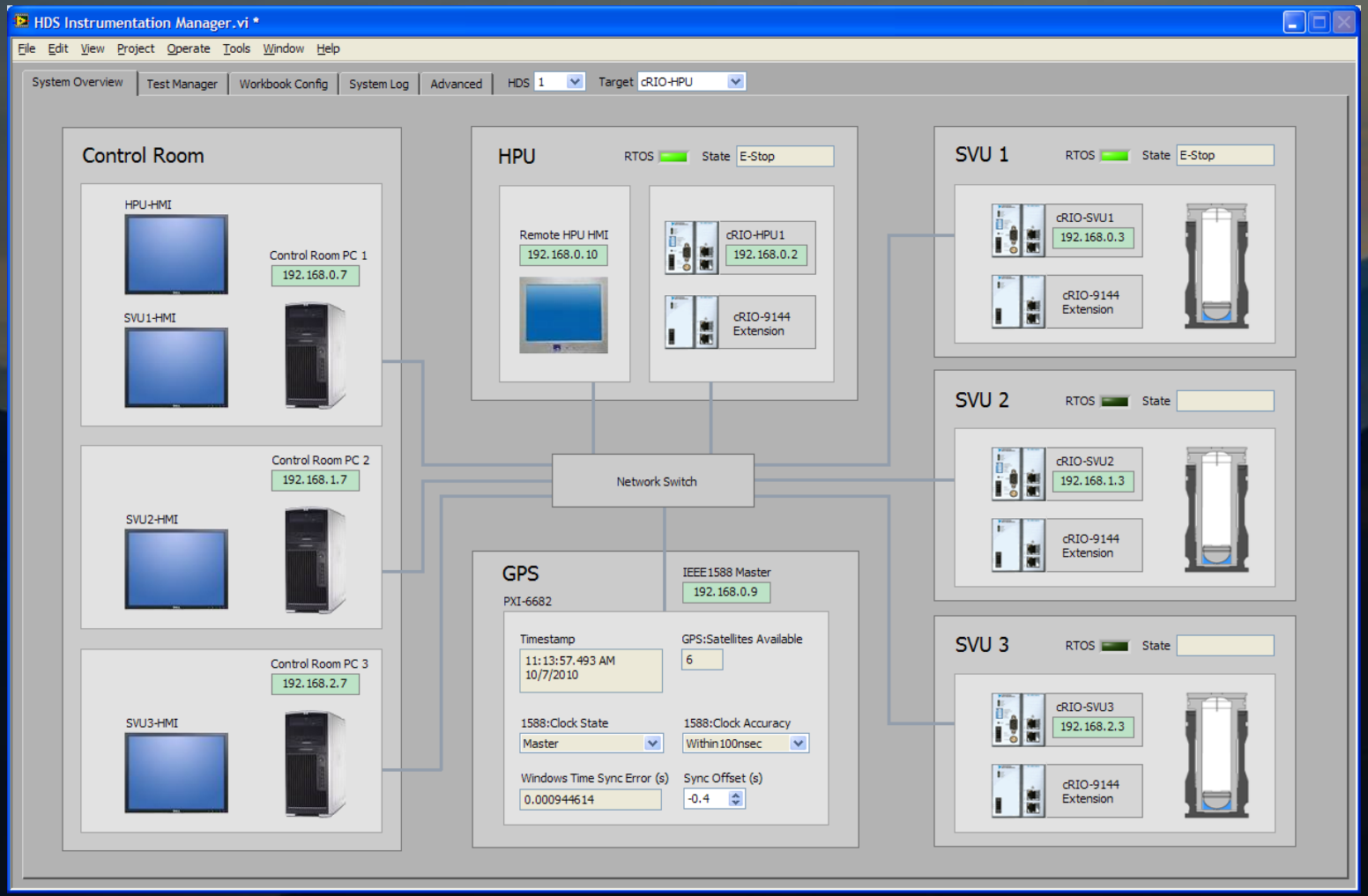
6. Diagnostics
   a. Multi-Tiered Alarm
   b. RT process Monitor
   c. Syslog, DSM



7. Safety/Reliability features (FMEA driven)
   a. Watchdog based ESTOP->Park
   b. Pump Dropout detection
   c. N2 pressure interlocks
   d. Bearing Contact monitor

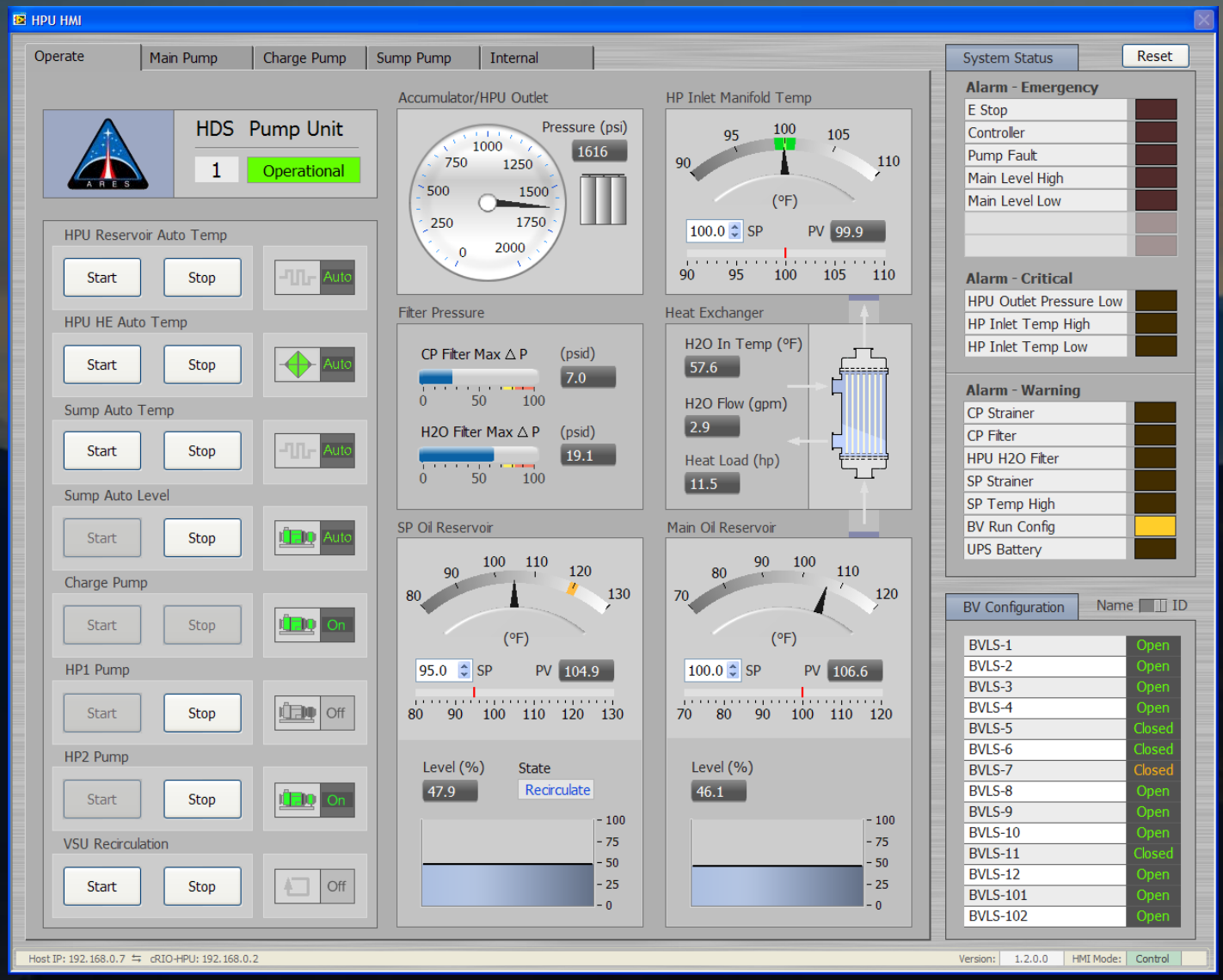
HDS Instrumentation Manager

One stop shopping for all your HDS configuration needs



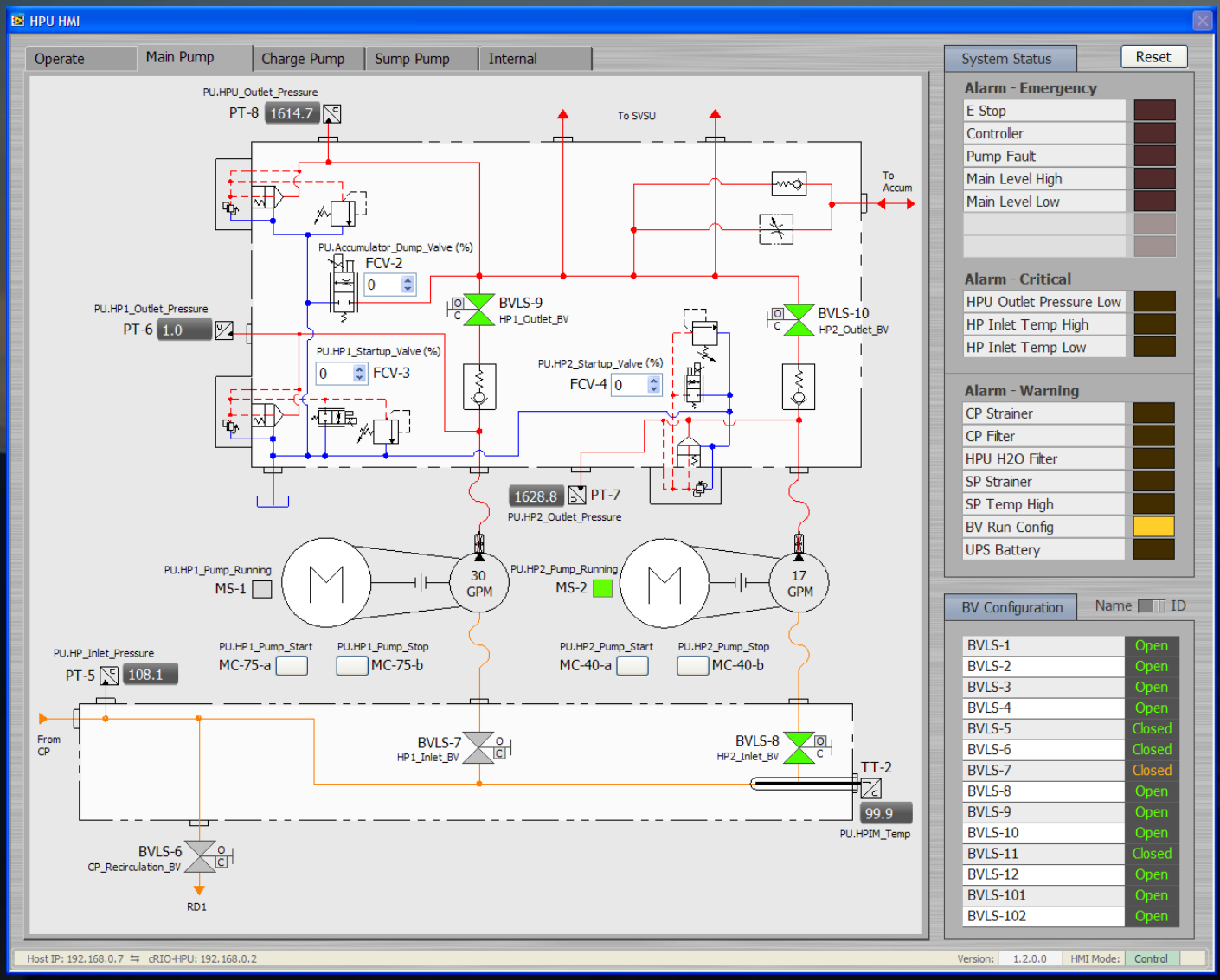
Overview of HDS networked devices, cRIO, HMI, PXI-6682

HPU HMI, Primary Operation Screen



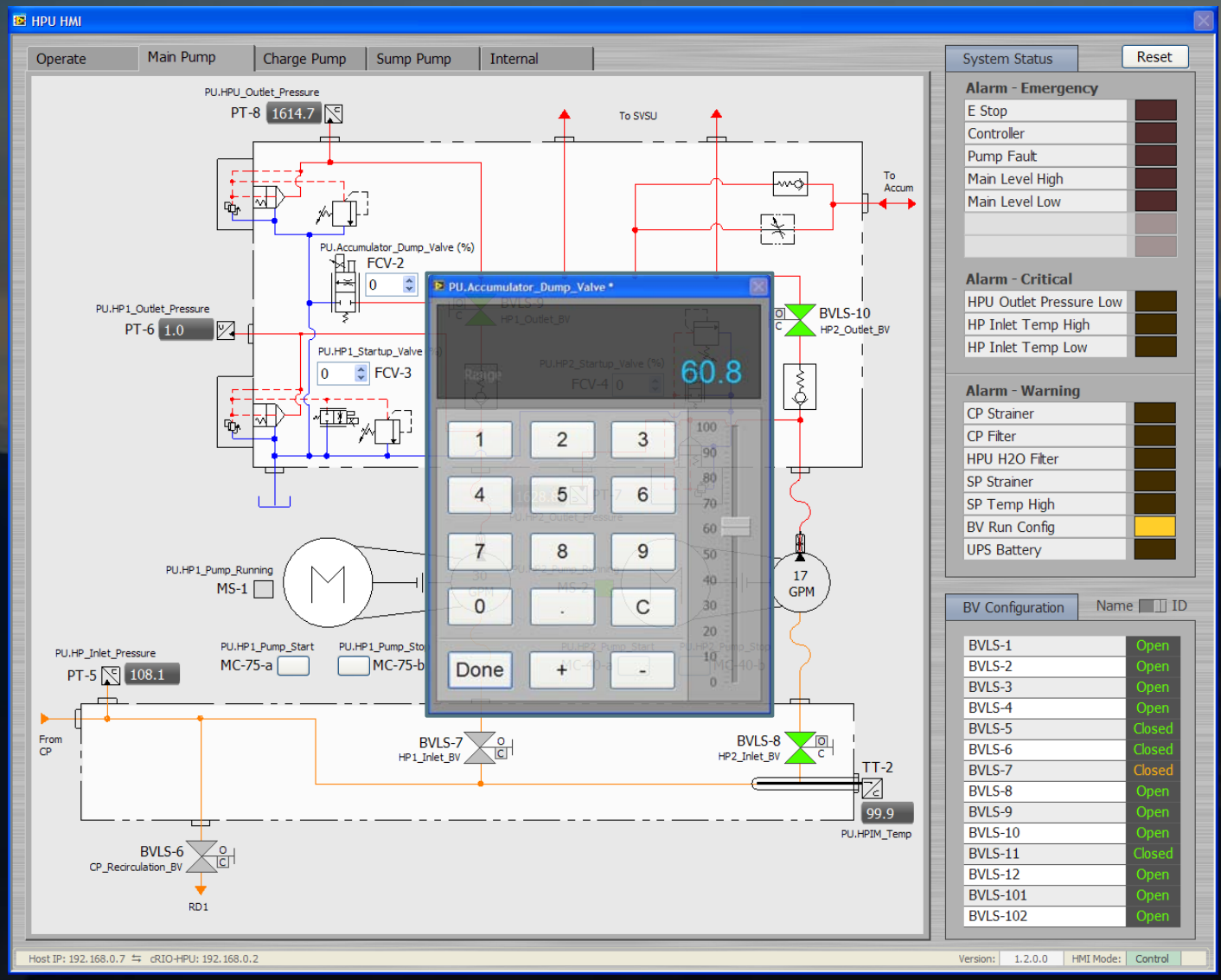
Pump Startup Sequencing, Tank Heater/Level, HE Temp Reg. +/- .2F, Filter Life Monitor

HDS HPU, Manual Pump Controls



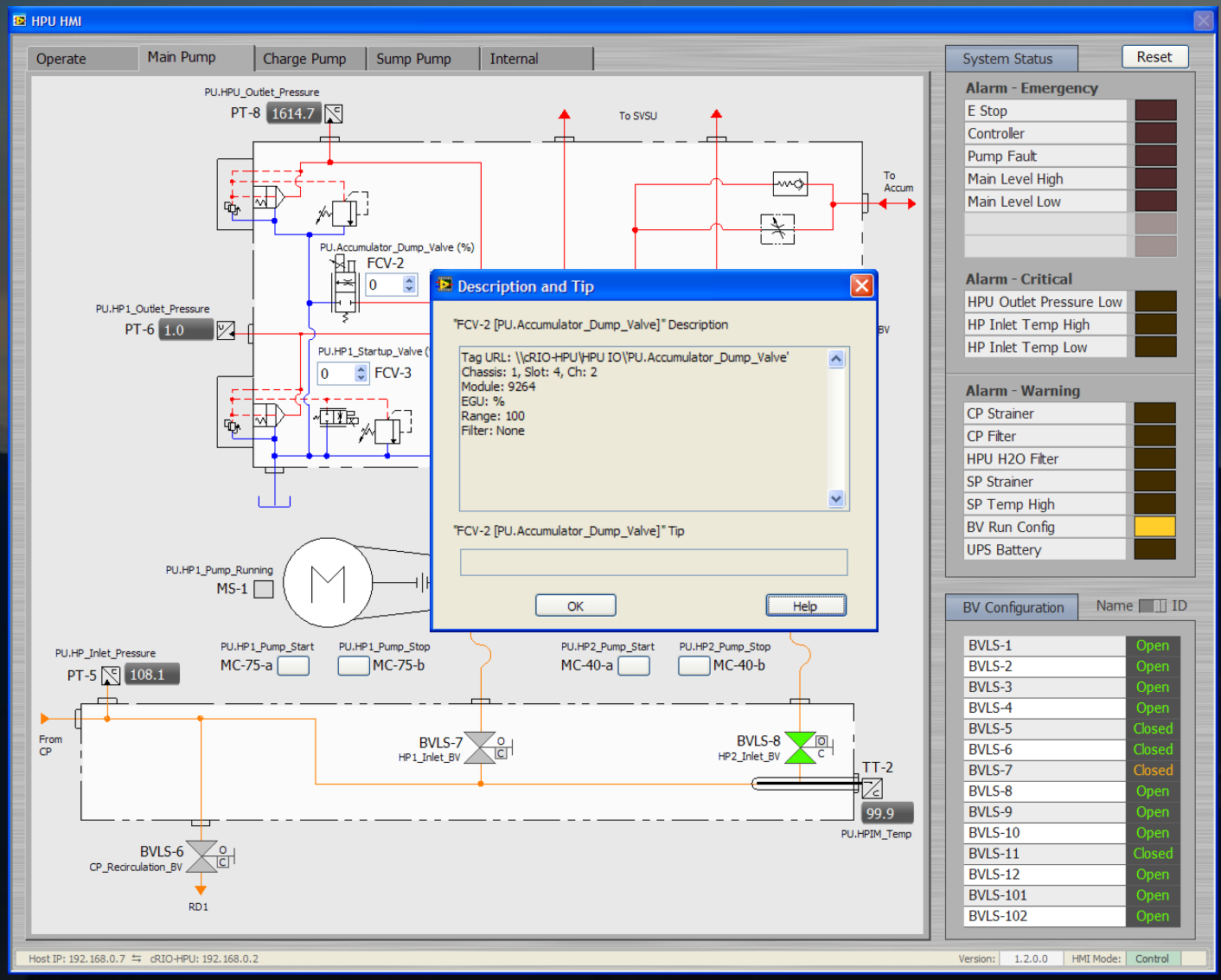
Touchpanel aware data entry, Tag ZOFS, Tag Stats Display

HDS HPU, Manual Pump Controls



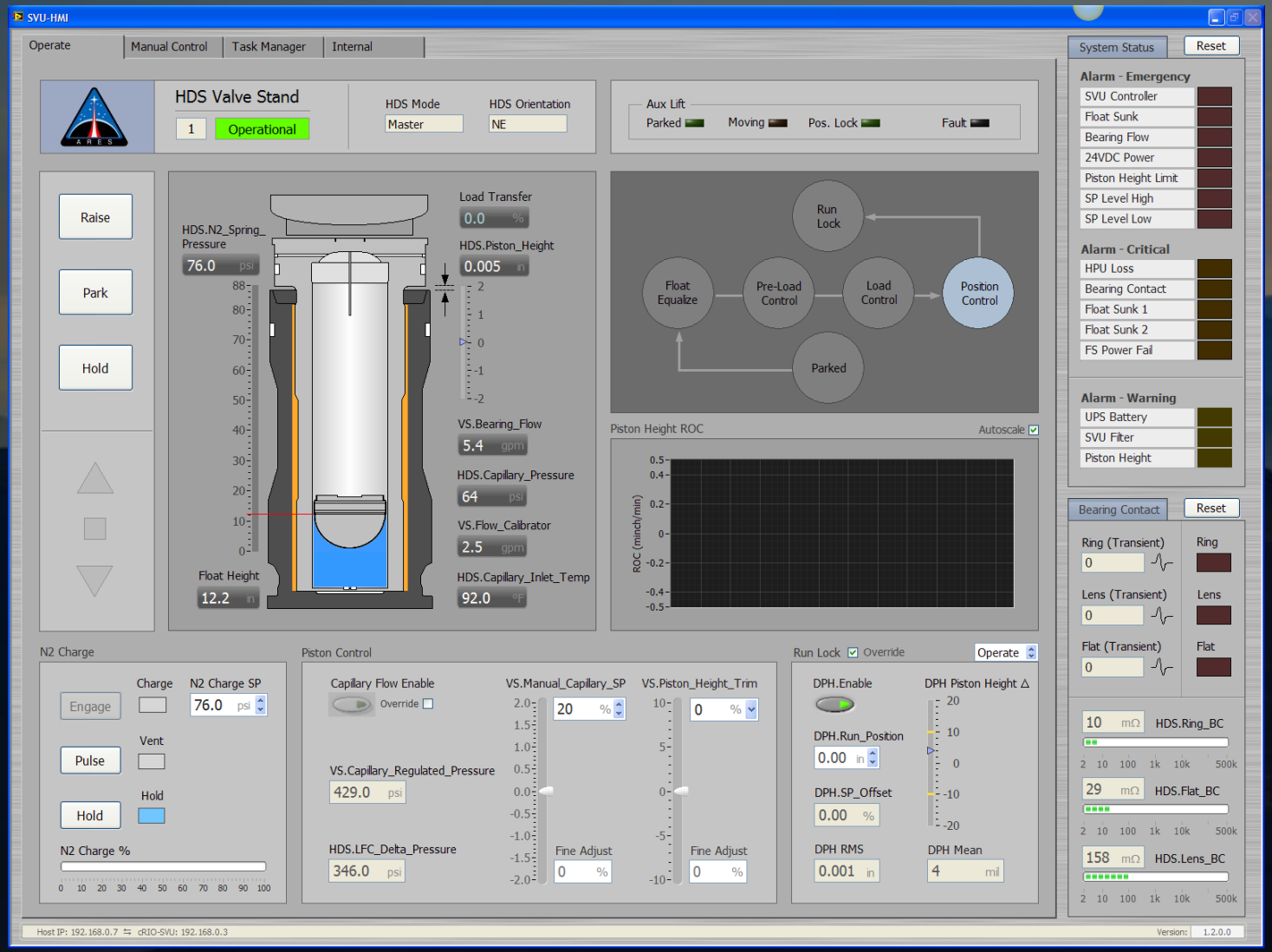
Touch Panel Numeric Data Keypad, activated by 2s touch on any control

HDS HPU, Manual Pump Controls



HMI tag stats display, right click on any control or indicator

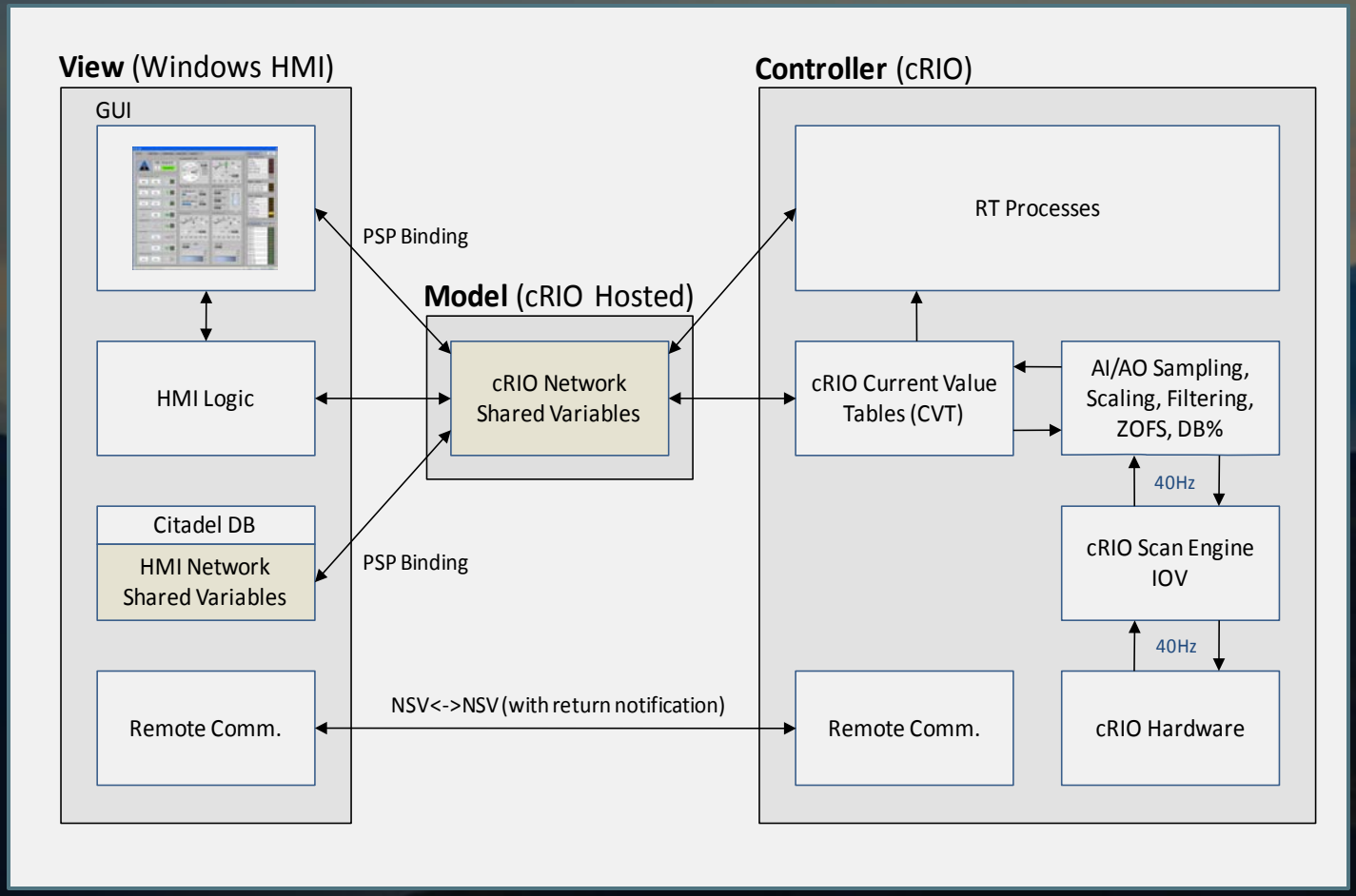
SVU HMI, Operate Screen



Individual and sync'd HDS control, N2 Autocharge, DPH (Dynamic Piston Height Control) dPH/dt, DPH Mean, HDS state, Bearing Contact Monitor (transient and persistent)

HDS Software Architecture

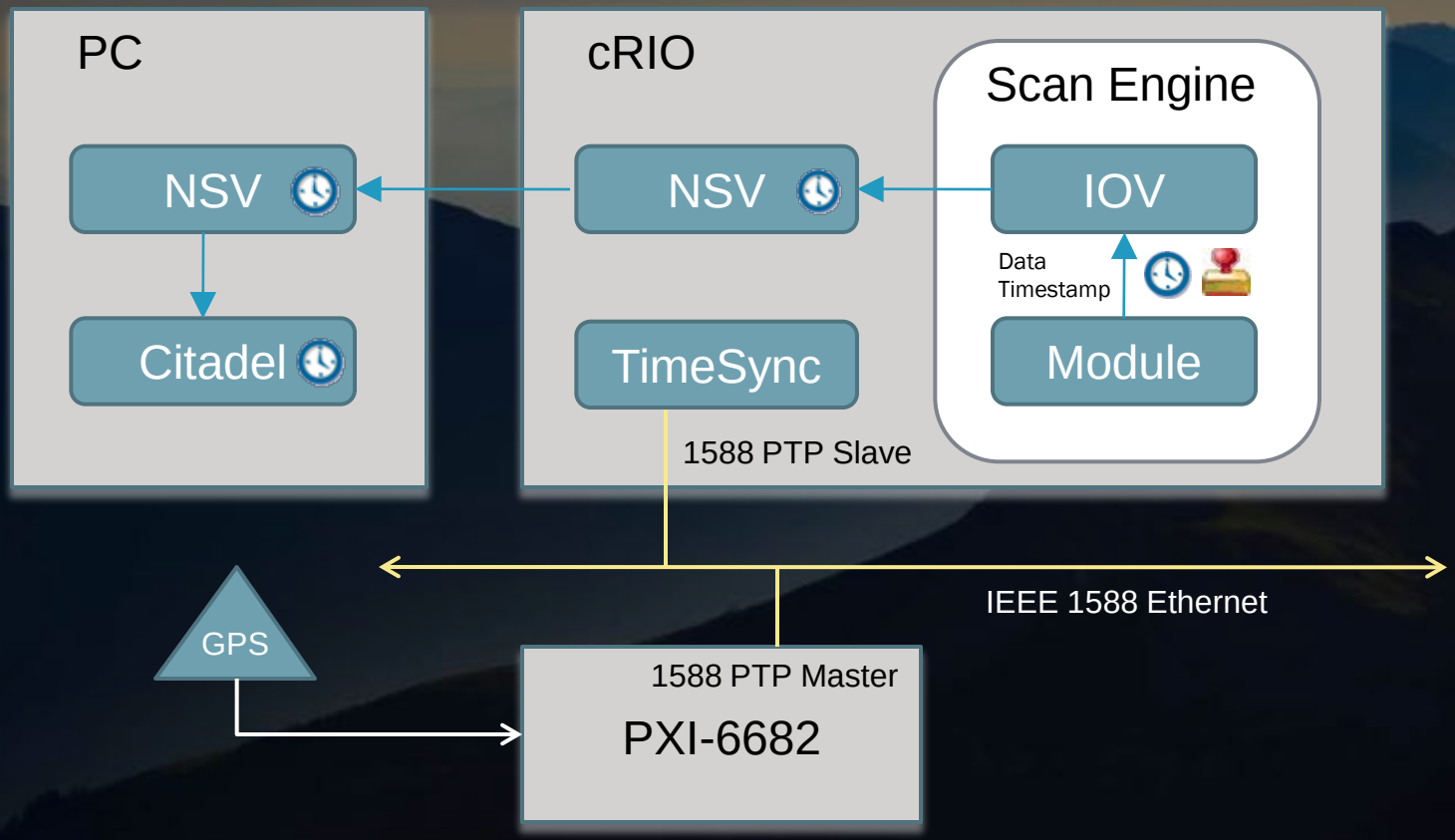
MVC (Model View Controller)



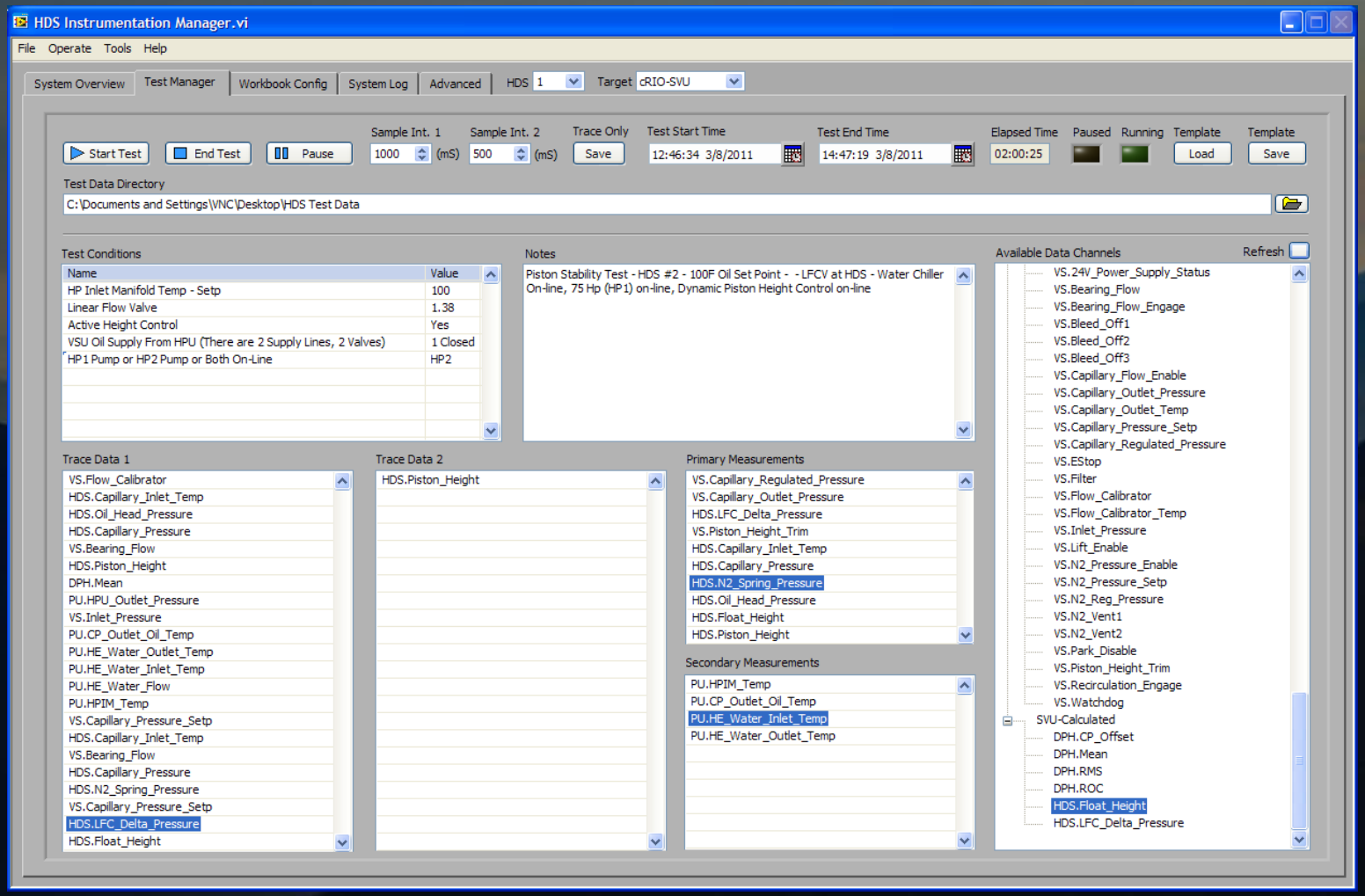
Model – SVE/PSP interface supports NSV bindings, events, static/dynamic NSV access

cRIO 1588 TimeSync

- IOV Timestamp by Module in Scan Engine
- IOV -> NSV binding preserves timestamp
- +/- 100us RT system time, +/- 1ms data timestamp



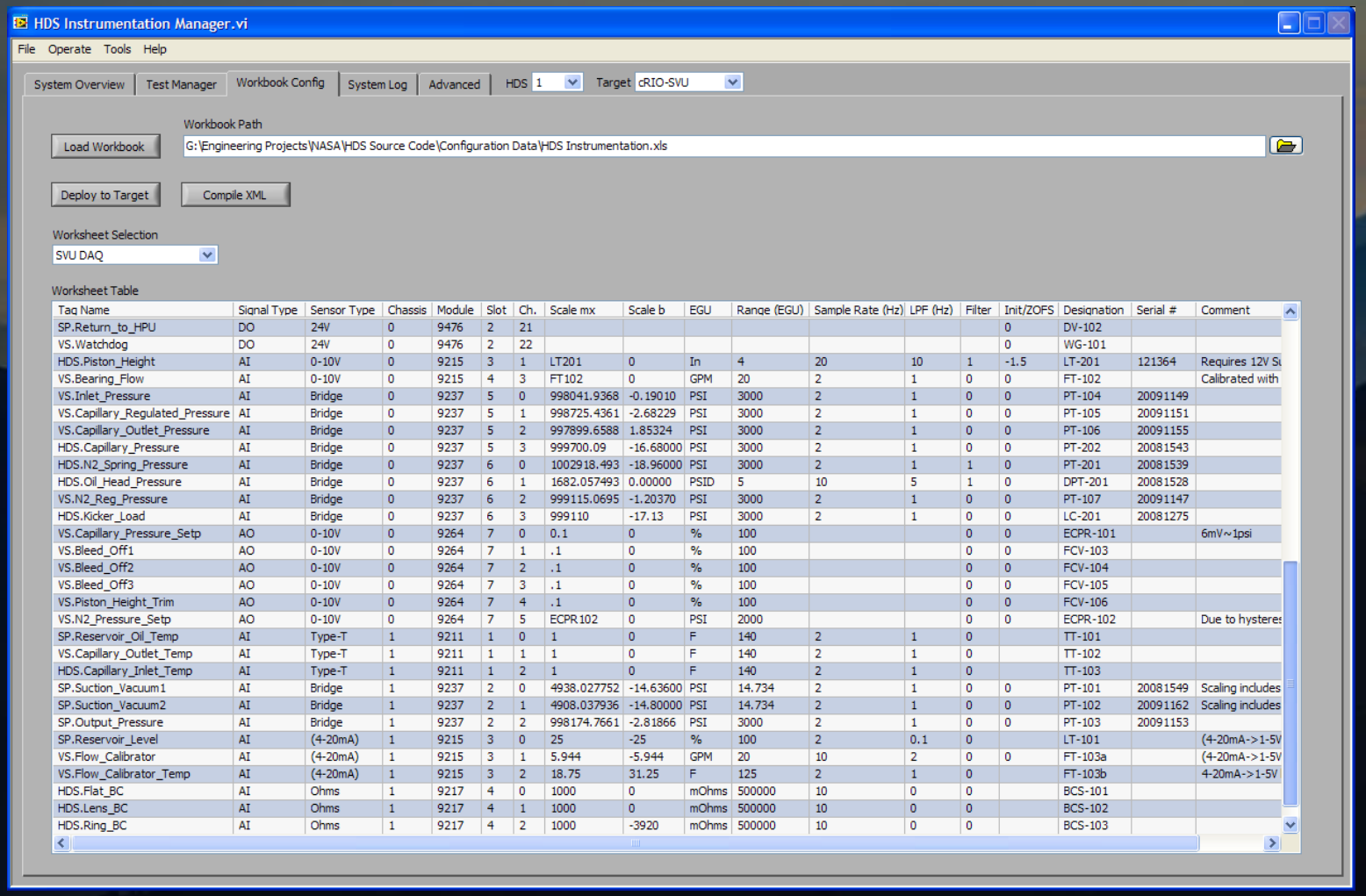
HDS Instrumentation Manager
Test Manager



Create test report templates defining data channels to be recorded during a test.
Upon test completion an excel workbook is populated with historical data and saved.

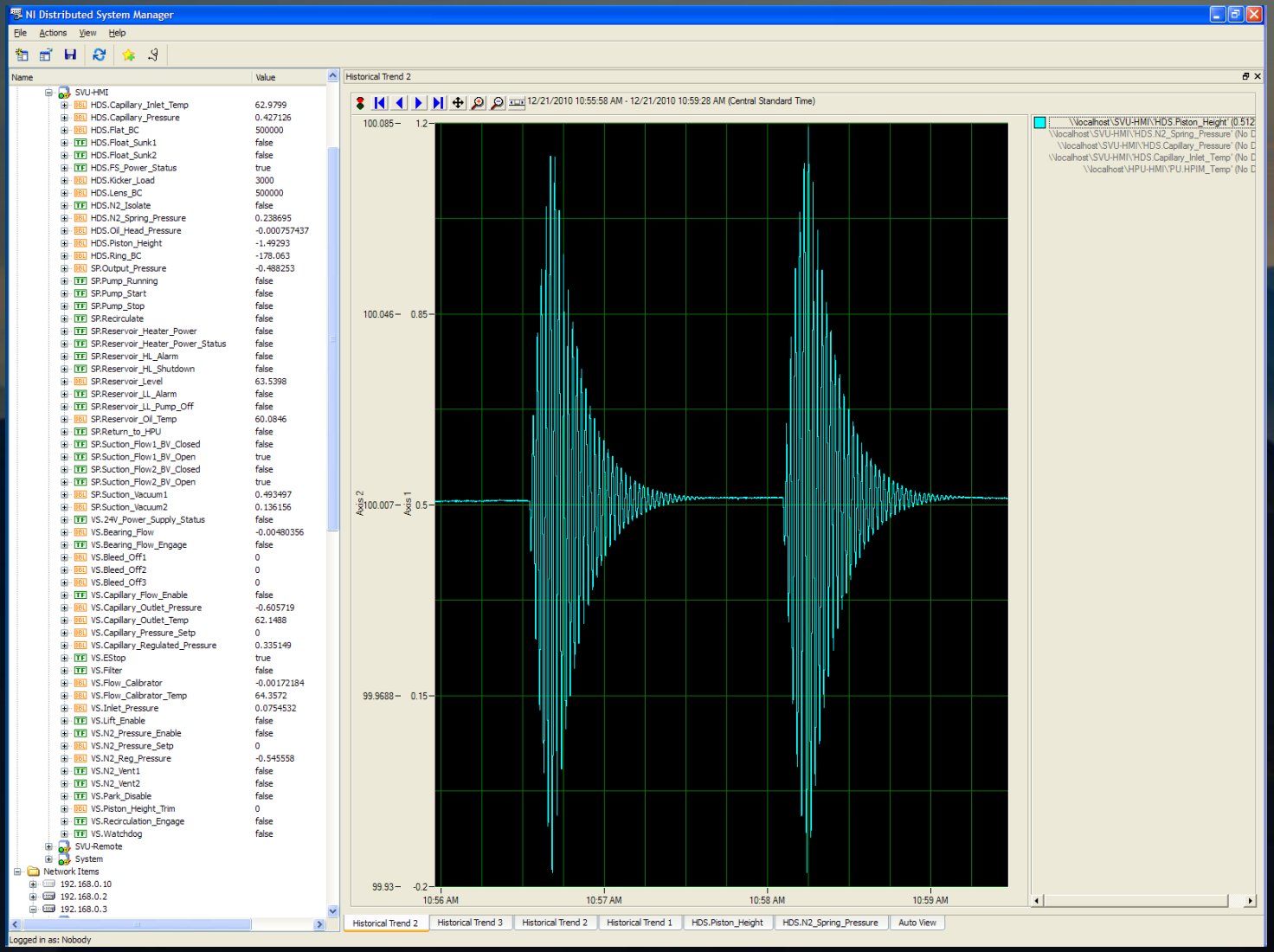
HDS Instrumentation Manager

Workbook Configuration, Compile to GXML -> Target



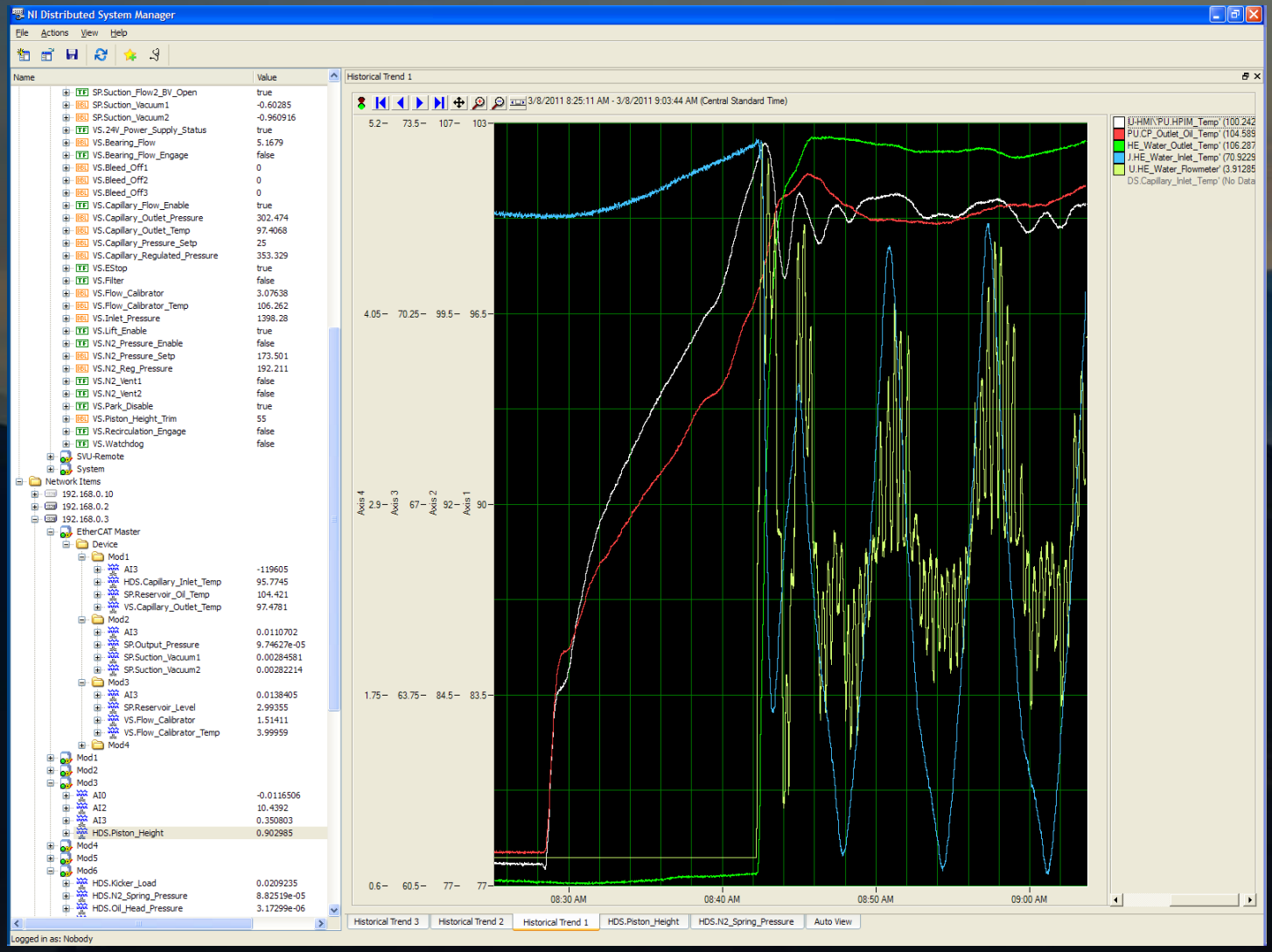
Tag Name	Signal Type	Sensor Type	Chassis	Module	Slot	Ch.	Scale mx	Scale b	EGU	Range (EGU)	Sample Rate (Hz)	LPF (Hz)	Filter	Init/ZOFS	Designation	Serial #	Comment
SP.Return_to_HPU	DO	24V	0	9476	2	21								0	DV-102		
VS.Watchdog	DO	24V	0	9476	2	22								0	WG-101		
HDS.Piston_Height	AI	0-10V	0	9215	3	1	LT201	0	In	4	20	10	1	-1.5	LT-201	121364	Requires 12V S
VS.Bearing_Flow	AI	0-10V	0	9215	4	3	FT102	0	GPM	20	2	1	0	0	FT-102		Calibrated with
VS.Inlet_Pressure	AI	Bridge	0	9237	5	0	998041.9368	-0.19010	PSI	3000	2	1	0	0	PT-104	20091149	
VS.Capillary_Regulated_Pressure	AI	Bridge	0	9237	5	1	998725.4361	-2.68229	PSI	3000	2	1	0	0	PT-105	20091151	
VS.Capillary_Outlet_Pressure	AI	Bridge	0	9237	5	2	997899.6588	1.85324	PSI	3000	2	1	0	0	PT-106	20091155	
HDS.Capillary_Pressure	AI	Bridge	0	9237	5	3	999700.09	-16.68000	PSI	3000	2	1	0	0	PT-202	20081543	
HDS.N2_Spring_Pressure	AI	Bridge	0	9237	6	0	1002918.493	-18.96000	PSI	3000	2	1	1	0	PT-201	20081539	
HDS.Oil_Head_Pressure	AI	Bridge	0	9237	6	1	1682.057493	0.00000	PSID	5	10	5	1	0	DPT-201	20081528	
VS.N2_Reg_Pressure	AI	Bridge	0	9237	6	2	999115.0695	-1.20370	PSI	3000	2	1	0	0	PT-107	20091147	
HDS.Kicker_Load	AI	Bridge	0	9237	6	3	999110	-17.13	PSI	3000	2	1	0	0	LC-201	20081275	
VS.Capillary_Pressure_Setp	AO	0-10V	0	9264	7	0	0.1	0	%	100			0	0	ECPR-101		6mV~1psi
VS.Bleed_Off1	AO	0-10V	0	9264	7	1	.1	0	%	100			0	0	FCV-103		
VS.Bleed_Off2	AO	0-10V	0	9264	7	2	.1	0	%	100			0	0	FCV-104		
VS.Bleed_Off3	AO	0-10V	0	9264	7	3	.1	0	%	100			0	0	FCV-105		
VS.Piston_Height_Trim	AO	0-10V	0	9264	7	4	.1	0	%	100			0	0	FCV-106		
VS.N2_Pressure_Setp	AO	0-10V	0	9264	7	5	ECPR102	0	PSI	2000			0	0	ECPR-102		Due to hysteres
SP.Reservoir_Oil_Temp	AI	Type-T	1	9211	1	0	1	0	F	140	2	1	0		TT-101		
VS.Capillary_Outlet_Temp	AI	Type-T	1	9211	1	1	1	0	F	140	2	1	0		TT-102		
HDS.Capillary_Inlet_Temp	AI	Type-T	1	9211	1	2	1	0	F	140	2	1	0		TT-103		
SP.Suction_Vacuum1	AI	Bridge	1	9237	2	0	4938.027752	-14.63600	PSI	14.734	2	1	0	0	PT-101	20081549	Scaling includes
SP.Suction_Vacuum2	AI	Bridge	1	9237	2	1	4908.037936	-14.80000	PSI	14.734	2	1	0	0	PT-102	20091162	Scaling includes
SP.Output_Pressure	AI	Bridge	1	9237	2	2	998174.7661	-2.81866	PSI	3000	2	1	0	0	PT-103	20091153	
SP.Reservoir_Level	AI	(4-20mA)	1	9215	3	0	25	-25	%	100	2	0.1	0		LT-101		(4-20mA->1-5V
VS.Flow_Calibrator	AI	(4-20mA)	1	9215	3	1	5.944	-5.944	GPM	20	10	2	0	0	FT-103a		(4-20mA->1-5V
VS.Flow_Calibrator_Temp	AI	(4-20mA)	1	9215	3	2	18.75	31.25	F	125	2	1	0		FT-103b		4-20mA->1-5V
HDS.Flat_BC	AI	Ohms	1	9217	4	0	1000	0	mOhms	500000	10	0	0		BCS-101		
HDS.Lens_BC	AI	Ohms	1	9217	4	1	1000	0	mOhms	500000	10	0	0		BCS-102		
HDS.Ring_BC	AI	Ohms	1	9217	4	2	1000	-3920	mOhms	500000	10	0	0		BCS-103		

DSM Historical Trend Capability



Manual Shake Test, Natural HDS damping characteristic

DSM Historical Trend Capability



New water chiller cycling disturbances

viScience.com

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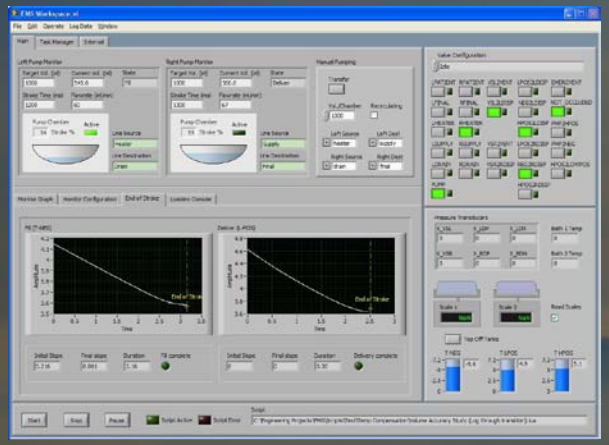

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