Gas House Autonomous System Monitoring
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ABSTRACT

Gas House Autonomous System Monitoring (GHASM) will employ Integrated System Health Management (ISHM) of cryogenic fluids in the High Pressure Gas Facility at Stennis Space Center. The preliminary focus of development incorporates the passive monitoring and eventual commanding of the Nitrogen System. ISHM offers generic system awareness, adept at using concepts rather than specific error cases. As an enabler for autonomy, ISHM provides capabilities inclusive of anomaly detection, diagnosis, and abnormality prediction. Advancing ISMH and Autonomous Operation functional capabilities enhances quality of data, optimizes safety, improves cost effectiveness, and has direct benefits to a wide spectrum of aerospace applications.
BACKGROUND

- Gas House provides gaseous Hydrogen, Nitrogen, Helium, and High Pressure Missile Grade Air to Stennis facilities
- Nitrogen and Hydrogen are stored as liquids and vaporized prior to delivery
- Cryogenic liquids are stored at very low temperatures and will boil when exposed to atmospheric heat
- Liquid Nitrogen boils at -321 degrees Fahrenheit
- Most gas house procedures are still operated manually
AUTONOMY

- Autonomous Operation (AO) requires no human intervention
- After unexpected events, AO continues towards the original or alternate objective
- AO incorporates adaptation, mitigation and re-planning
- Autonomy is not absolute
- Automatic vs. Autonomous
INTEGRATED SYSTEMS HEALTH MANAGEMENT

- Generic system awareness capability
- Error prediction based on historical data
- Automation of complex procedures
- Tested and integrated at Kennedy Space Center - Cryogenic Testbed Laboratory
ISHM MONITORING CAPABILITIES*

- Sensor Anomalies
- Valve Anomalies
- Leak Detection
- Flow Propagation
- Diagnostics

*Concept and model based
Nitrogen System

- Liquid Nitrogen is delivered by truck and stored in one 55,000 gallon backup reservoir.
- Two 28,000 gallon tanks and a 27,000 gallon tank are used as primary storage.
- Liquid is pulled from the tanks and pumped through three Skid Pumps to vaporizers for conversion to gas.
- Gaseous commodity is then pushed to the site for use.
DESIGN APPROACH

- Toolkit is written using the G2 software platform (Gensym)
- The Nitrogen system is divided into 22 distinct schematic sheets
- Each sheet represents a functional unit
- All technical information on a sheet will be preserved
- Sheets must be visually separate but connected programmatically
- ISHM Toolkit objects will be used to ensure genericity
- Newly added objects and procedures will be pushed to the toolkit
- All components will be represented by their functional counterparts in the toolkit
- Every connection will have a piping section between the two objects
COMPONENT IDENTIFICATION
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- Pressure Transducer
- Pressure Indicator
- Reducer
- 3-Way Solenoid Valve
- Check Valve
- Connection Post
- Restrictive Orifice
- Globe Valve
- Level Indicator
DESIGN TRADE-OFFS

♦ Icons can lack visual accuracy and require extensive time allotted for design
♦ Icons are restricted to rectangles, leaving gaps between connections on contoured objects
♦ G2 has no “undo” functionality
♦ Programming syntax in G2 can be convoluted
  ♦ Ex. “for locsend = each item upon the workspace of Thing do”
HM-NOTE-FLAG

- Visual representation linking schematic notes to the corresponding objects
- Clicking a note flag will temporarily highlight associated objects
- Number indicator represents amount of objects affected

<table>
<thead>
<tr>
<th>Linka</th>
<th>RO-2289</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linkb</td>
<td>RO-2271</td>
</tr>
</tbody>
</table>

6. Maintenance Responsibility belongs to Test Operations Contractor (TOC).
7. Restrictive orifices are valves with seats removed to work as variable restricting orifices.
ACS-LABEL-VIEW

- Preserves sheet notes within ISHM Domain
- Contains authoritative signatures
- Each field is populated by an attribute of the instance
- Clicking the “Label Sheets” button will refresh the display fields
HM-SUBWORKSPACE-SKID

- Represents Nitrogen Skid Pumps
- Inputs of various connection types are handled with the subworkspace
- Valves are toggled by the status of the skid-motor
HM-SKID-MOTOR

- HM-Skid-Motor represents the motor driving each skid
- Controls the discrete valves within the skid over an “axle connection”
HM-AXLE-CONNECTION

- *Hm-axle-connection* represents a physical axle running between the Skid motor and the pistons within the skid
- Creates a link between the skid pump and enclosed discrete motor valves
- When the motor is on, the discrete motor valves will be simulated as open
ACD-NITROGEN-PUMP (Operational Screen)

✧ Represents skids within the display domain
✧ Provides click access to informational and commanding screens

![Operational Screen Diagram]
HM-CONTROLLER-PIC

◊ Utilizes pressure upon a pneumatic piston to actuate an opening, thus controlling the flow of commodity

◊ This controlled flow is then used as pneumatic actuation input to control another valve
◊ Represents a centrifugal boost pump within the ISHM display domain
◊ Modified from existing solution to function in any orientation
HM-DISCHARGE-MANIFOLD

- Fluid path element that distributes liquid Nitrogen between multiple channels
- Serves as a hub to connect multiple piping sections (13 in our application)
HM-DISPLAY-LUBE-OIL-UNIT

- Provides pressurized lubrication oil to each of the skids
- Exhibits crucial status information about the entire Lube Oil Systems
HM-3WAY-RELIEF-VALVE

- Used to relieve pressure in a segment of pipe when the pressure exceeds a specific threshold
- Pressure threshold is relieved by allowing commodity to flow through an auxiliary pathway to atmosphere
HM-PLUG

◊ A plug is a convenient solution for preventing the flow of commodity at the end of piping section.

◊ The plug helps to bind a piping subsystem within the ISHM Domain
**DISP-SMALL-FLOWPIPE**

- Used to highlight alternate commodity flow path in the display domain
- Disp-flowpipe outlines the primary flow path
Disp-Site-Pressure visually represents the overall site pressure of Stennis Space Center.

- Skids respond automatically to given pressure threshold
  - Above: deactivate
  - Below: activate
OPERATIONAL SCREENS

◊ It’s crucial that users only see information pertinent to system operations and functionality

◊ On the Display Domain, each object is of the display class and is linked to an ISHM object with the identical key

◊ Highlight important sensors, valves, and controls essential for optimal processing at the High Pressure Gas Facility

◊ Commodity state is represented by blue (liquid) or yellow (gaseous) piping colors
PROFESSIONAL GROWTH

- Experience developing software in an expert/knowledge system environment for intelligent operations
- Involvement with intellectually charged, inspiring team in a challenging atmosphere
- Contributions to project expansions at Kennedy Space Center
- Interactions with operators currently using the system
- Exposure to cryogenics engineering
FUTURE GOALS

- Incorporation of programmable logic controller (PLC)
- Installation of passive monitoring system at facility
- Active commanding of the Nitrogen System
- Integration with the Hydrogen System