Physics Simulation Software for Autonomous Propellant Loading and Gas House Autonomous System Monitoring

Bjorn Constantine Regalado Reyes
University of Texas – Pan American
Mentors: Dr. Fernando Figueroa and Mark Turowski

National Aeronautics and Space Administration

Abstract

Physics Simulation Software for Autonomous Propellant Loading

Kennedy Space Center (KSC) is developing a mobile launching system with autonomous propellant loading capabilities for liquid-fueled rockets. An autonomous system will be responsible for monitoring and controlling the storage, loading and transferring of cryogenic propellants. The Physics Simulation Software will reproduce the sensor data seen during the delivery of cryogenic fluids including valve positions, pressures, temperatures and flow rates. The simulator will provide insight into the functionality of the propellant systems and demonstrate the effects of potential faults. This will provide verification of the communications protocols and the autonomous system control and monitoring functions.

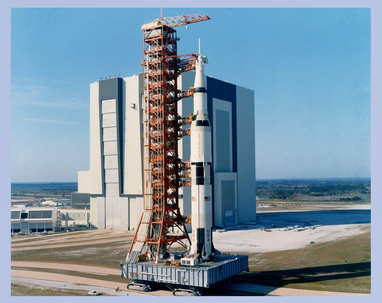
Gas House Autonomous System Monitoring

The High Pressure Gas Facility (HPGF) stores and distributes hydrogen. nitrogen, helium and high pressure air. The hydrogen and nitrogen are stored in cryogenic liquid state. The cryogenic fluids pose several hazards to operators and the storage and transfer equipment. Constant monitoring of pressures, temperatures and flow rates are required in order to maintain the safety of personnel and equipment during the handling and storage of these commodities. The Gas House Autonomous System Monitoring software will be responsible for constantly observing and recording sensor data, identifying and predicting faults and relaying hazard and operational information to the operators.

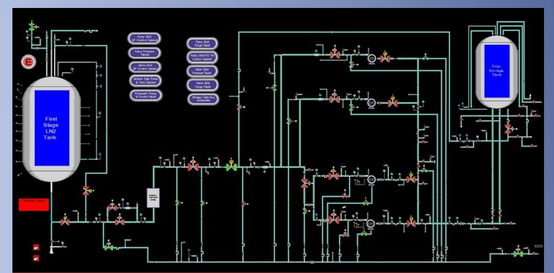
Introduction

Cryogenic Fluids
"Cryogenic Fluids may loosely be defined as those fluids whose normal boiling temperatures at atmospheric pressure are below 273K." [1]

Autonomous Propellant Loading
Provide automated handling of propellants for mobile launching capability



High Pressure Gas Facility
This Facility stores and distributes hydrogen, nitrogen, helium and high pressure air. These gases are required to be in a pressurized environment and kept at cryogenic temperatures



G2 Application of a Liquid Nitrogen System

Objectives

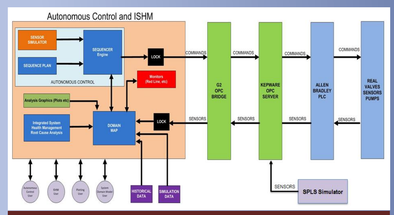
Physics Simulation Software
- Pressure Sensor
- Temperature Sensor
- Valve Feedback

Data →
← Commands

Monitoring and Control Systems

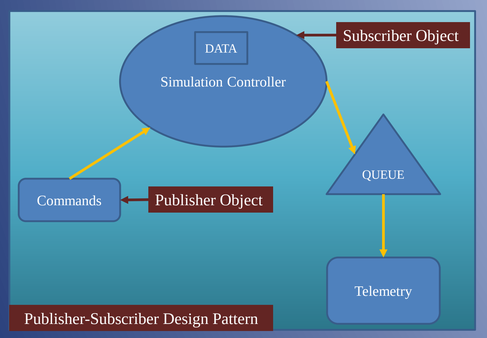
- Simulate sensor data such as pressures and temperatures based on mathematical models
- Respond to commands by changing simulation state
- Ensure proper communications between control software and hardware

- Design and develop a G2 workspace to represent the Liquid Nitrogen system components
- Use G2's real-time processing capabilities and rule-based expert system for fault detection

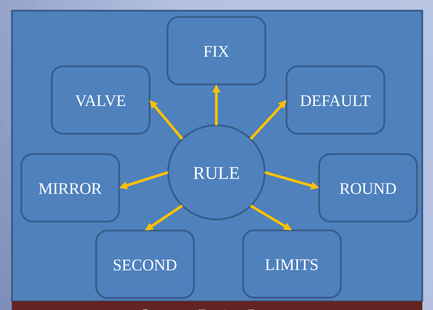


Autonomous Control and ISHM Integration Architecture

Approach



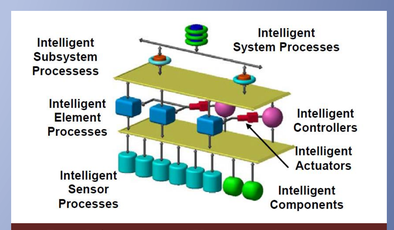
Publisher-Subscriber Design Pattern



Strategy Design Pattern

- Utilize Object-Oriented Programming with an emphasis on reusability
- Employ Design Patterns to avoid common pitfalls
- Implement standardized communication (Space Packet Protocol) [2]

- Utilize Integrated Systems Health Management (ISHM) concepts [3]
- Utilizing ISHM toolkit developed in partnership with General Atomics
- Object-Oriented Programming



Data, Information and Knowledge Architecture

Results

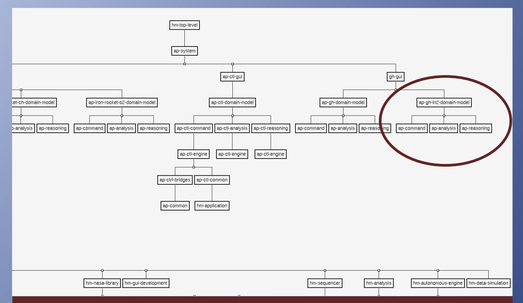
```
GL02LU9XPMPP1OFP\PT-10-02-P (FLOAT) => 100.00004

[143569378636] FINER: Packet: Space Packet Protocol Packet
Packet Status: Valid
Packet Version Number: 0
Packet Type: TELEMETRY
Secondary Header: NOT_PRESENT
Application ID: APID101
Sequence Flag: UNSEGMENTED
Sequence Count: 39
Packet Length: 23
Packet Data: 0000000000000000000000000000000000403F801F40200
APL Application Data
GL02LU9VOISS11BY\SV-11-02-OPN-S (BOOLEAN) => 0
GL02LU9VOIPS16BY\SV-16-02-OPN-S (BOOLEAN) => 0
GL02LU9VOIPS15BY\SV-15-02-OPN-S (BOOLEAN) => 0
GL02LU9VOIPS13BY\SV-13-02-OPN-S (BOOLEAN) => 0
GL02LU9VOIPS09BY\SV-9-02-OPN-P (BOOLEAN) => 0
GL02LU9VOIPS08BY\SV-8-02-OPN-P (BOOLEAN) => 0
GL02LU9VOIPM08BY\MAV-8-02-OPN-P (BOOLEAN) => 0
GL02LU9VOIPM07BY\MAV-7-02-OPN-P (BOOLEAN) => 0
GL02LU9VOIPM06BY\MAV-6-02-OPN-P (BOOLEAN) => 0
GL02LU9VOIPM05BY\MAV-5-02-OPN-P (BOOLEAN) => 0
GL02LU9VOIPM04BY\MAV-4-02-OPN-P (BOOLEAN) => 0
GL02LU9VOIPM03BY\MAV-3-02-OPN-P (BOOLEAN) => 0
GL02LU9VOIPM02BY\MAV-2-02-OPN-P (BOOLEAN) => 0
GL02LU9VOIPA03BY\AMAV-3-02-OPN-P (BOOLEAN) => 1
```

Simulation Sample Output

- Successful Integration with Monitoring and Control Systems
- Used static code analysis tools to analyze code for correctness and identify and correct known bugs
- Verification and Validation performed in multi-system testing environment

- Created a Domain Model for Liquid Nitrogen Process Equipment
- G2 Workspace created for Liquid Nitrogen System
- Integrated into overall monitoring application



Integrated Nitrogen Domain Model Module

References
1) Weisend, J. G. *Handbook of Cryogenic Engineering*. Philadelphia, PA: Taylor & Francis, 1998. Print 2) United States of America. National Aeronautics and Space Administration. Council of the Consultative Committee for Space Data Systems. SPACE PACKET PROTOCOL. Blue Book ed. Vol. Issue I. N.p.: n.p., n.d. CCSDS 133.0-B-1. CCSDS. Web. 11 June 2015. 3) Figueroa, Fernando, and Kelvin Melcher. Integrated Systems Health Management for Intelligent Systems. Proc. of Infotech at Aerospace, St. Louis, Missouri. Print.

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