NPAS Physics Pump Models for Autonomous Monitoring

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Overview

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- Background
- Project Objectives
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Introduction

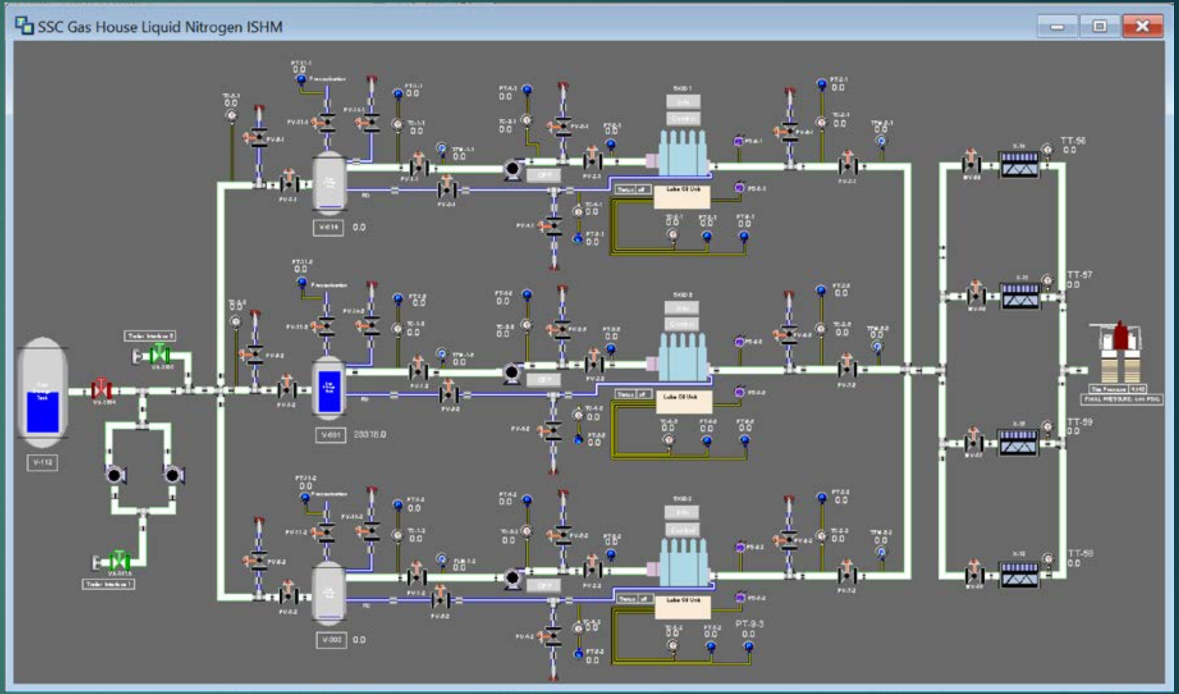
- **Major:** Biomedical Engineering
- **College:** Elgin Community College in Elgin, Illinois
- **Prior to Internship:**
  - NASA Community College Aerospace Scholar
  - Biomedical Engineering Volunteer
  - Taekwondo Instructor

Background

- NPAS is a platform for autonomous operations developed at SSC's Autonomous Systems Laboratory (ASL)

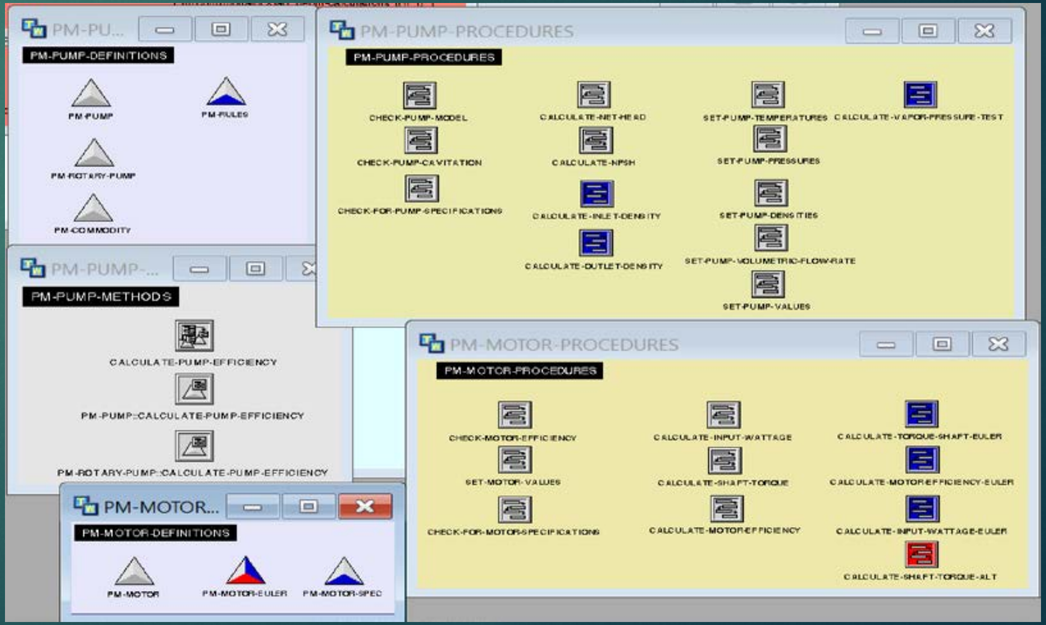
- The Intelligent Stennis Gas House Technology (INSIGHT) is a project that uses NASA Platform for Autonomous Systems (NPAS) to implement autonomous operations at the Gas House

- Initially INSIGHT is implementing autonomous operations of the Nitrogen system



Background From Previous Interns

- Andrew Yeo, a former NASA intern, provided the theory of how the centrifugal pump should work and left behind equations and parameters to begin coding in NPAS
- Former Interns Kyle Bentain and Wilson Barce laid the groundwork for reasoning using the physics pump model



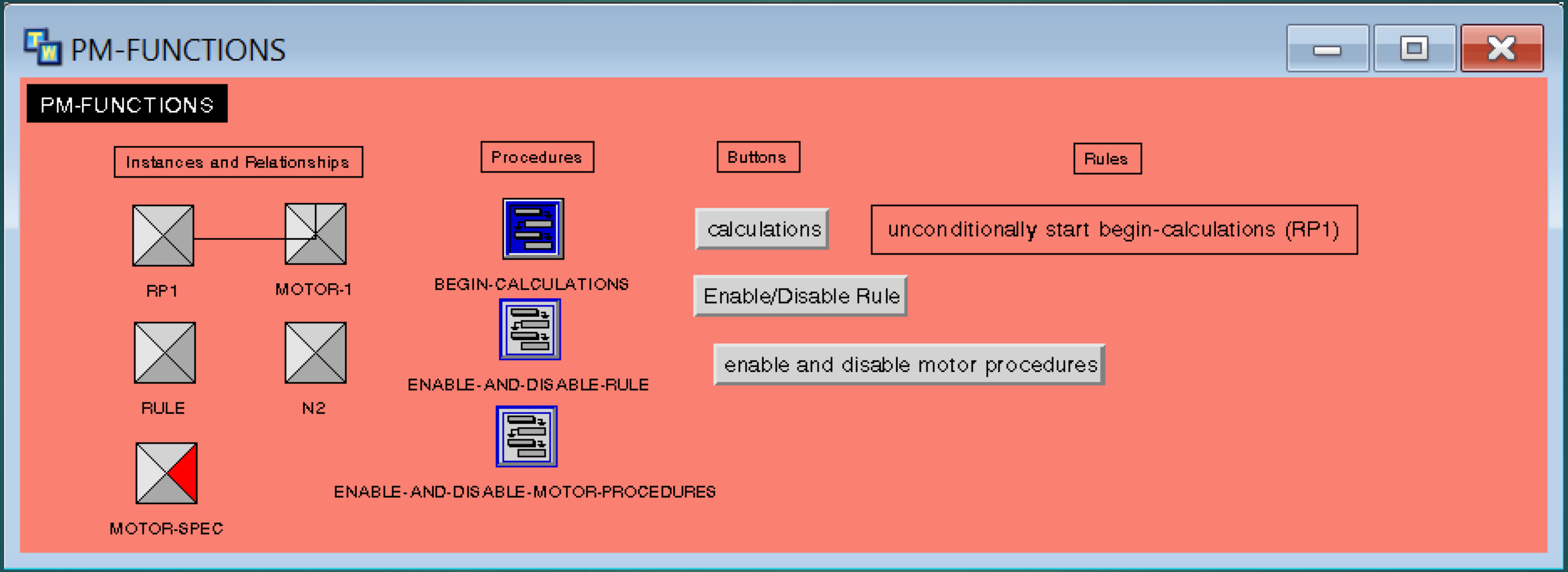
Project Objectives

- Learn how to program using the G2 Software environment
- Create procedures and methods to detect cavitation in a centrifugal pump and other features such as efficiency
- Verify that the code and theory work by implementing test cases
- Begin implementation of the generic rotational pump model package for the High Pressure Gas Facility

Solutions

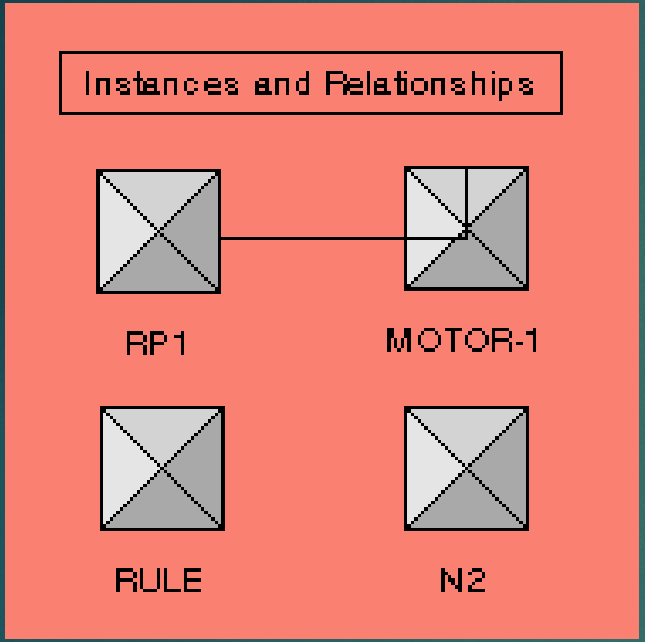
- Created a workspace to test the code of the previous interns and modified the code as needed
- Acquired data at the High Pressure Gas Facility to verify calculations
- Create rules to make relevant calculations automatically in 5 second intervals

PM-Functions workspace



This workspace was used to simulate a running pump and motor

Instances/Objects



- Each instance is a representation of an object that is used at the Gas House with the exception of the “RULE” instance (more on that later)
- RP1 represents a centrifugal pump that is connected to MOTOR-1
- The connectivity automatically enables use of the linked motor and pump parameters in the modeled equations
- N2 represents the commodity that is being passed through the pump (RP1), which is Liquid Nitrogen
- RULE is used to disable and enable the use of the model when needed

Attributes

MOTOR-1, a pm-motor

UUID	"f890fe30d95211e88139d4258bf7213b"
Notes	OK
Item configuration	none
Names	MOTOR-1
Motor torque constant	1.246
Gearbox reduction ratio	4.91
Rotational speed	3525.0
Specified operating amperage	34.4
Specified operating voltage	460.0
Specified motor efficiency	0.95
Input amperage	18.0
Input wattage	8280.0
Shaft torque	110.121
Motor efficiency	0.781

RP1, a pm-rotary-pump

UUID	"bd2afa43db8911e88139d4258bf7213b"
Notes	OK
Item configuration	none
Names	RP1
Commodity	n2
Flow order	50
Inlet diameter	2.5
Outlet diameter	1.5
Inlet height	2.0
Outlet height	6.0
Specified net positive suction head	4.6
Inlet pressure	18.5
Outlet pressure	118.7
Inlet temperature	-317.7
Outlet temperature	-313.5
Volumetric flow rate	92.3
Inlet density	0.029
Outlet density	0.025
Net head	5.031
Pump efficiency	0.627
Net positive suction head	8.451
Allowable model error	0.357

N2, a pm-commodity

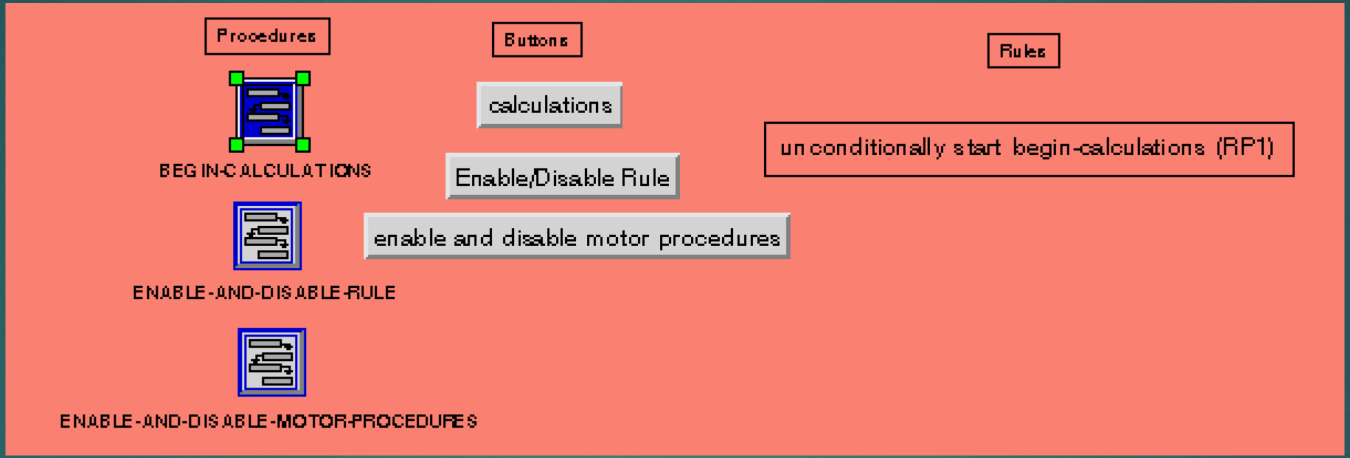
UUID	"c3572739c68611e88136d4258bf7213b"
Notes	OK
Item configuration	none
Names	N2
Isothermal coefficient	13.98
Specific heat capacity	0.486
Vapor pressure	0.057

RULE, a pm-rules

UUID	"781d99afde0611e8813ad4258bf7213b"
Notes	OK
Item configuration	none
Names	RULE
X	0

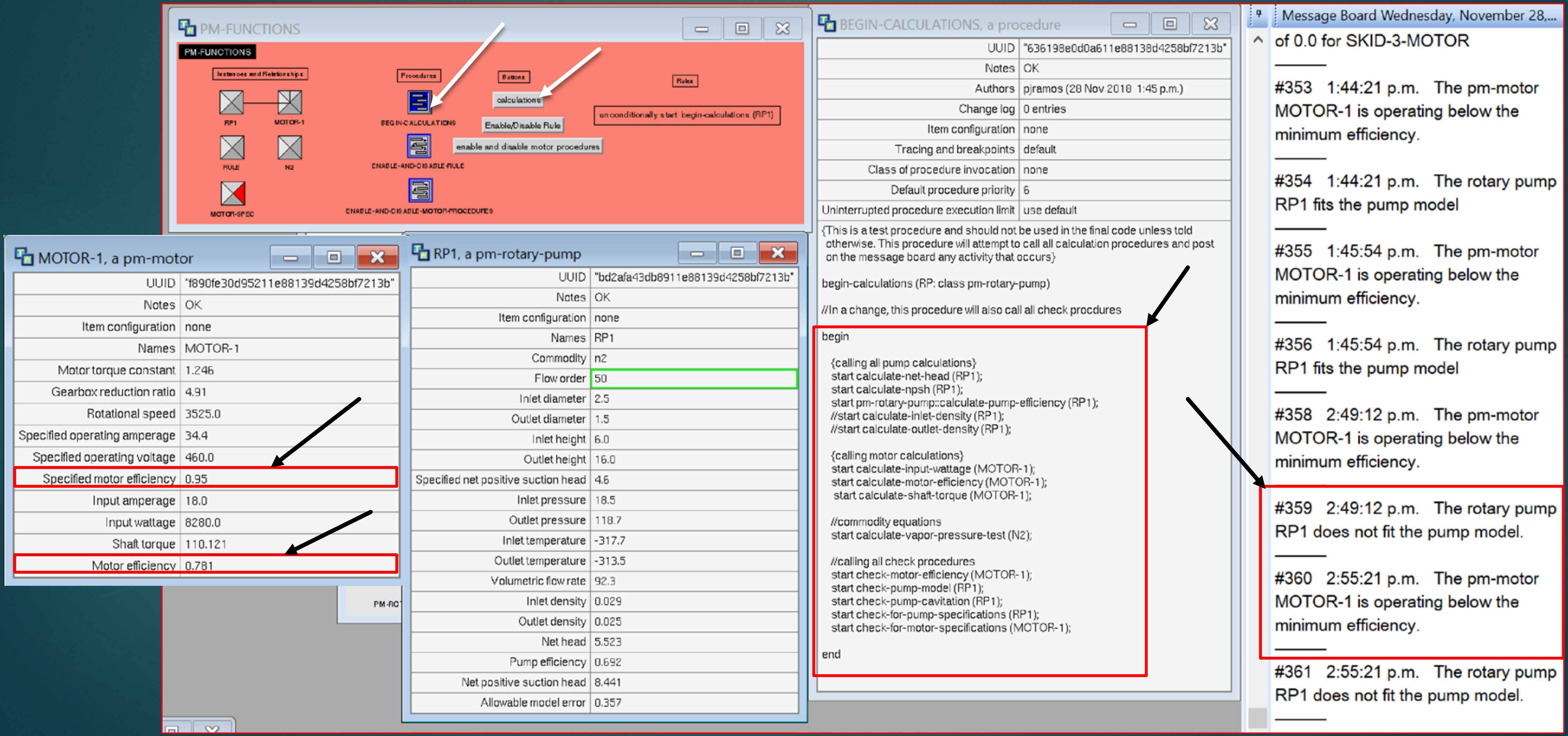
- Each instance contains a set of attributes
- The attributes in this case hold raw data and calculations
- These calculations are made through procedures and methods
- Raw data was collected by reading pressure, temperature, and flow rate sensors at the HPGF

Procedures, Rules, and Buttons

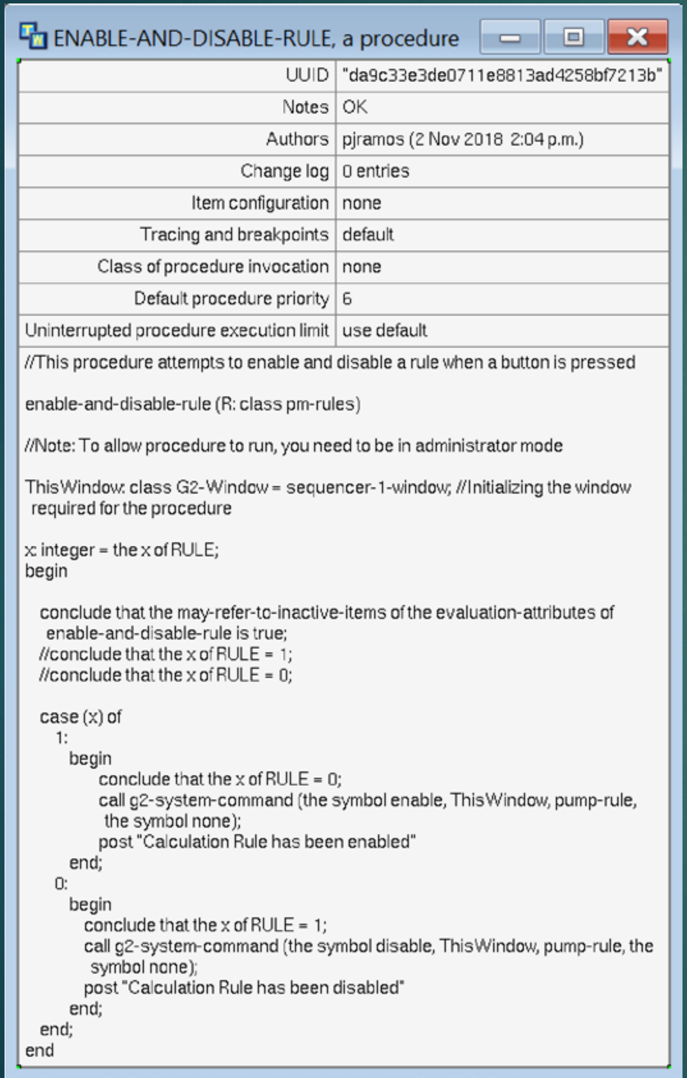


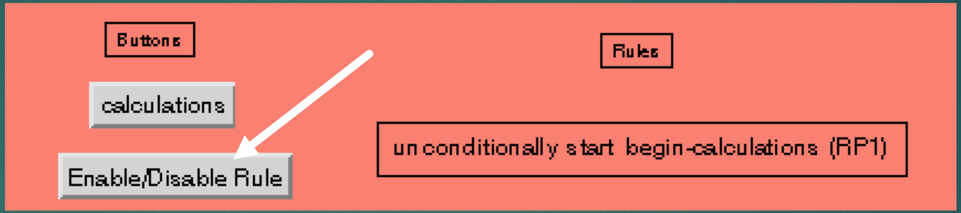
- The following procedures have different functionalities:
  - Begin-calculations calculates all attributes of a class through the use of a button
  - Enable-and-disable-rule turns a rule on/off when in administrator mode
- Buttons trigger these procedures to begin
- Rules were used to have the procedures run automatically

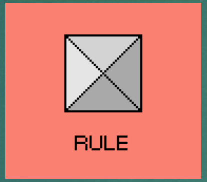
Procedures, Rules and Buttons (cont.)

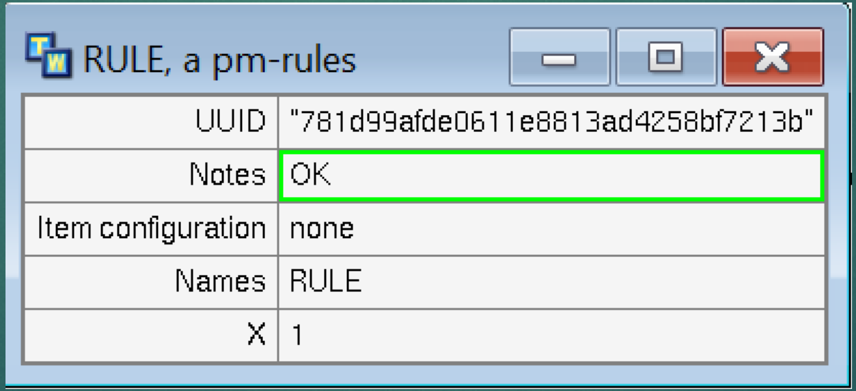


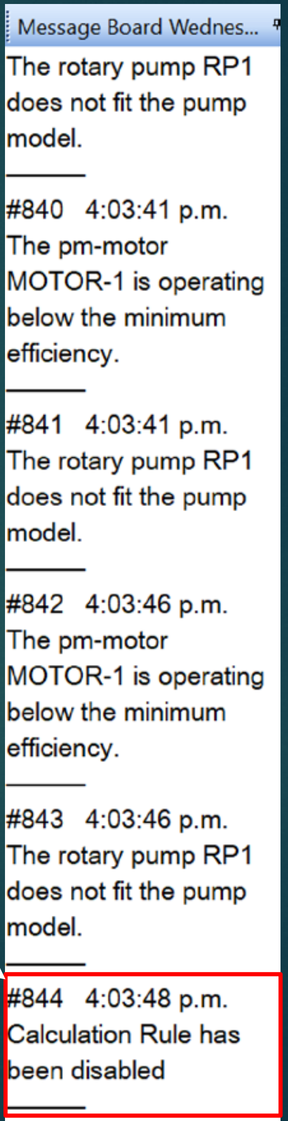
Programmatically Disabling and Enabling a Rule



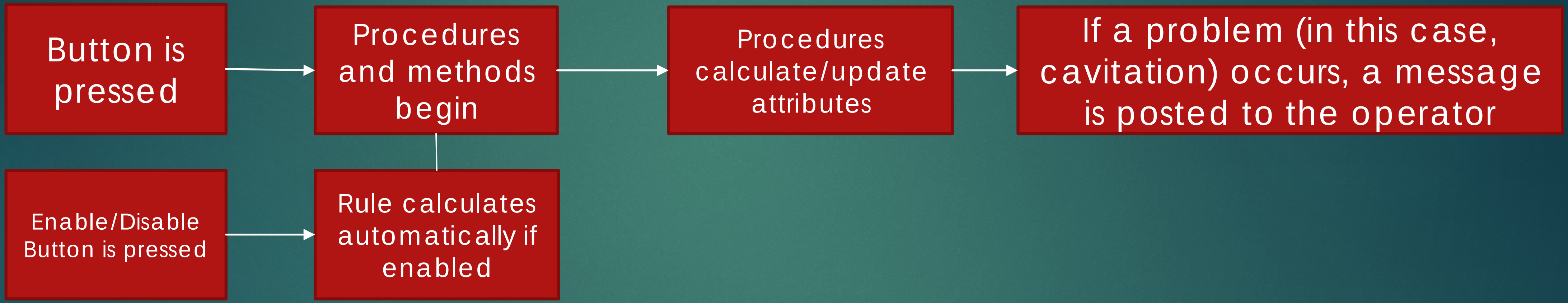








Logic


Button is pressed
Procedures and methods begin
Procedures calculate/update attributes
If a problem (in this case, cavitation) occurs, a message is posted to the operator
Enable/Disable Button is pressed
Rule calculates automatically if enabled

Common Problems

- One of the biggest problems when running a procedure lied within the units being used for each equation
- As a way to distinguish the required units, documentation and comments were made for each procedure to keep all units uniform to the equations
- Miscellaneous equation errors

UNITS:

Length/Distance: Inches (in)

Weight: Pounds (lbs)

Time: Minutes (min)

Volume: Gallons (G) * {in^3 for calculations)} [conversion factor: *231]

Pressure: Pounds per square-inch (psi)

Density: Pounds per cubic inch (lbs/in^3)

Rotational Speed: Revs/Minute (rpm) {rev/s for calculations} [conversion factor: * 1/60]

Linear Speed: Inches per second (in/s)

Volumetric Flow Rate: Gallons per minute (GPM) {in^3/s for calculations} [conversion factor: * 3.85]

Gravitational Constant: inches per second^2 (in/s^2)

Power: in-lbs/s

** Note: When doing calculations, convert all units to pounds, inches, and seconds

Importance of ISHM

- The Integrated System Health Management (ISHM) is a component of NPAS that utilizes 4 functionalities:
  - Anomaly Detection
  - Diagnositcs
  - Prognostics
  - Integrated Awareness
- Each of these functionalities work hand in hand to detect a problem in a system and to predict possible outcomes.

Moving Forward

- Further develop symcure functionalities for root-cause analysis
- Implementation to the Gas House
- Implementing a saturation table that include temperature, pressure, and density

Lessons Learned

- How to program in the G2 Software environment
- Familiarity and coding for NPAS
- Application of physics in real world situations
- The properties of cryogenics and liquid nitrogen and their affects in the operations at Stennis Space Center
- How the Gas House system functions

Skills Acquired

- Programming for the first time
- Coding using object-oriented programming
- Project management using scrum
- Root cause analysis
- Physics models for rotary pumps and motors

Future Plans

Spring 2019
Finish ECC with an Associates in Engineering Science

Fall 2019
Transfer to the University of ????

Spring 2020
Co-Op?

Future
Graduate with a Bachelors in Biomedical Engineering

Graduate School
Masters in Biomedical Engineering

Acknowledgements

- Fernando Figueroa, NASA Mentor
- Andrew Tidwell, D2K Contractor
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Thank You NASA!