# ENHANCING THE RESILIENCE AND RELIABILITY OF SINGAPORE'S LNG/GAS ASSETS: A PRESCRIPTIVE MAINTENANCE AND SELF-CONFIGURING CONTROL FRAMEWORK USING BIGDATA AND MACHINE LEARNING

## PROJECT SUMMARY

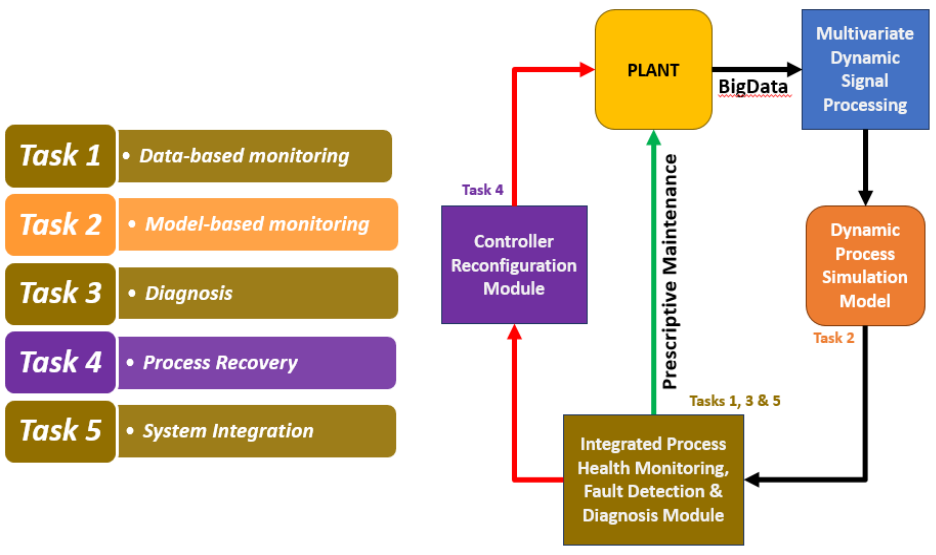
Natural gas is critical to Singapore's power and energy needs.

- SLNG Terminal and SP PowerGas (SPPG) network are two key assets in Singapore's gas infrastructure.
- Zero tolerance in gas supply disruption in Singapore requires the development of smart tools to ensure the highly reliability and smooth operations of these assets.

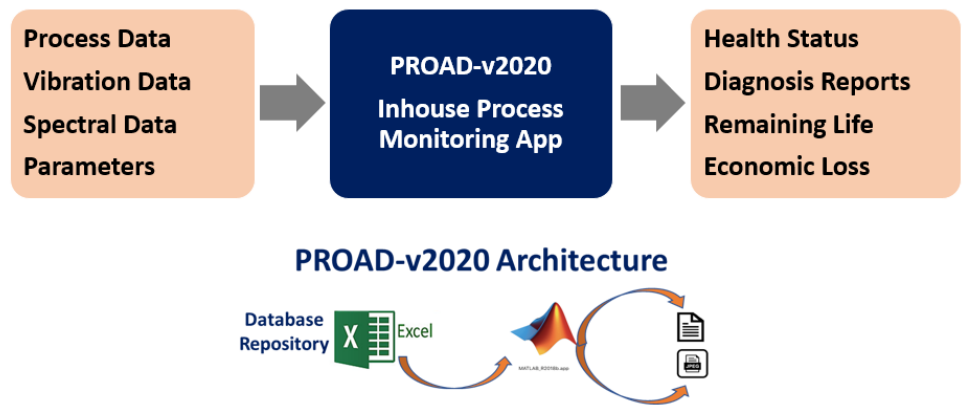
**Objective:** This project seeks to develop a smart automated framework and proof-of-concept tool for the prescriptive maintenance and self-configuring control of SLNG Terminal & SPPG Gas network.

**Methodology:** A mix of data-based and first-principles-model-based machine learning approaches, which involves:

- Integration of five well-designed tasks (*Fig. 1*); and
- Development of a tool called PROAD (ProcessAdvisor) *(Fig. 2*) with a user-friendly Graphical User Interface (GUI).




*1. Overview of methodology: Data acquisition, followed by selection of relevant sets of data and data preprocessing. Processed data is used to build models that are employed for prescriptive maintenance and amendments to control loops.*




*2. PROAD architecture: Data input is via well-directed, interactive, and robust MS-EXCEL templates. Data is analyzed through a series of algorithms in MATLAB and finally, the health status of the relevant asset along with a diagnostic report and information on RUL and economic loss Is provided.*

## PROJECT OUTCOMES

**Key Developments:**

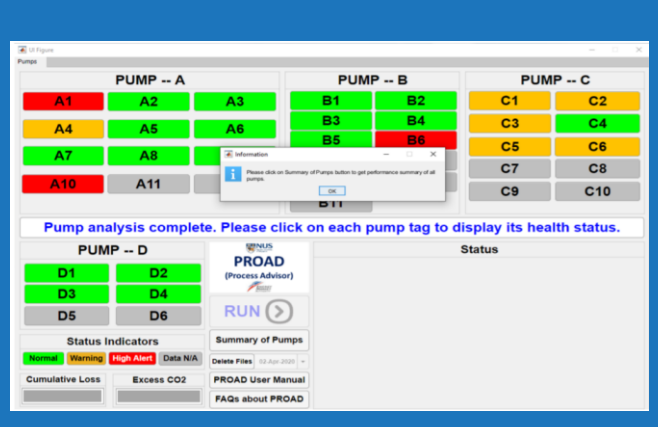
- A digital twin has been developed with a methodology for monitoring, diagnosis and prescriptive maintenance of SLNG and SPPG's assets.
- **With SLNG,** the digital twin was developed for the expanded terminal, including assets such as pumps, compressors, insulations, filters, and critical control loops.
  - Color-coded health status is indicated on the pump monitoring dashboard (*Fig. 3*) of which, an analysis of deviations overtime is used to compute remaining useful life (RUL) and spectral data is analysed for identifying mechanical faults.
  - The control loop performance dashboard (*Fig. 4*) provides summary descriptive statistics on the controlled and manipulated variables. Information on constraint violation and saturation of valves is also contained.
- **With SPPG,** the digital twin was modelled for pressure regulators.
  - The pressure regulator monitoring dashboard (*Fig. 5*) shows the plots of input pressure data and the predicted flow rate.
  - This is done by combining the developed methodology with available data to monitor the advent of faults (e.g. filter choking, valve seat damage, diaphragm deterioration) and track their prognosis and estimate RUL.

**Key Innovation:**

✓Ability to separate abnormal process conditions from abnormal equipment health.
✓Designed to detect instantaneous faults as well as gradual deterioration.
✓A generic tool: Can be used for similar assets in other plants.

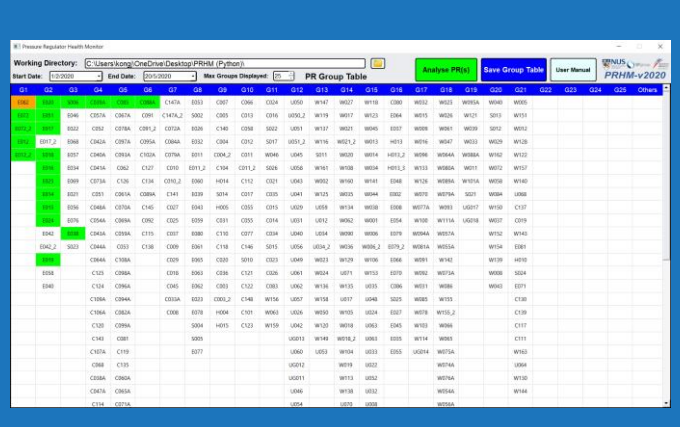
**Success Stories at SLNG:**

- Booster pumps : Severe bearing damage was detected by PROAD for one of the booster pumps.
- Reloading Pumps: Flow turbulence was detected by PROAD, which is usually a precursor to cavitation.
- Helped SLNG plan maintenance for the pumps and saved them precious turndown time of a few days.




*3. Pump monitoring dashboard*


*4. Control loop performance dashboard*




*5. Pressure regulator monitoring dashboard*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