A Focus On Balance

A Novel Approach Taking the Phillips Optimized Cascade LNG Process Into the Future

Prepared for AIChE Spring National Meeting
April 2003, New Orleans
LNG I – Operation and Reliability

Presentation Agenda

- Introduction
- Setting the Perspective
- Current Phillips Optimized Cascade LNG Process
- An Alternate Approach
- Furthering The Approach
- Conclusions

Introduction
- Variables To Balance -

- **Variables**
  - **CAPEX**
  - **OPEX**
    - Availability, Reliability, Maintainability, Production Efficiency, Onstream Factor, Capacity Factor
    - Thermal Efficiency
  - **Schedule**
- **Analysis**
  - **Life Cycle Cost**
    - RAM Analysis
  - **NPV**
- **More Difficult Concepts**
  - **Process Stability, Process Flexibility, Historical Deviation(s)**

Introduction
- Defining the Variables -

- **CAPEX**
  - **Include Entire Integrated Facility**
    - Battery Limit Through Storage & Loading, Including Utilities
  - **Total Installed Cost Basis - Exclude Owner's Cost**

- **Thermal Efficiency**
  - **(HHV Products)/(HHV Feed)*100**
  - **All Products**
  - **Entire Facility Including Offsites & Utilities**

- **RAM Results**
  - **Life Cycle Basis**
  - **Entire Facility Including Offsites & Utilities**

Introduction
- Defining the Variables Continued -

- Availability (Up Time/Total Time)
  - Calculation: MTTF/(MTTF + MTTR + Mean Logistics Delay)*100
  - Useful for Comparing Total Downtime of Various Options, Critical Sparing Philosophy, and Other Downtime Related Variables

- Production Efficiency
  - Calculation: (Predicted Prod/Required Prod)*100
  - Useful for Life Cycle Cost Analysis
  - More Appropriate Measure of LNG Produced

- Predicted -vs- Achieved
  - Should Be Able to Reconcile

Introduction
- Balancing the Variables -

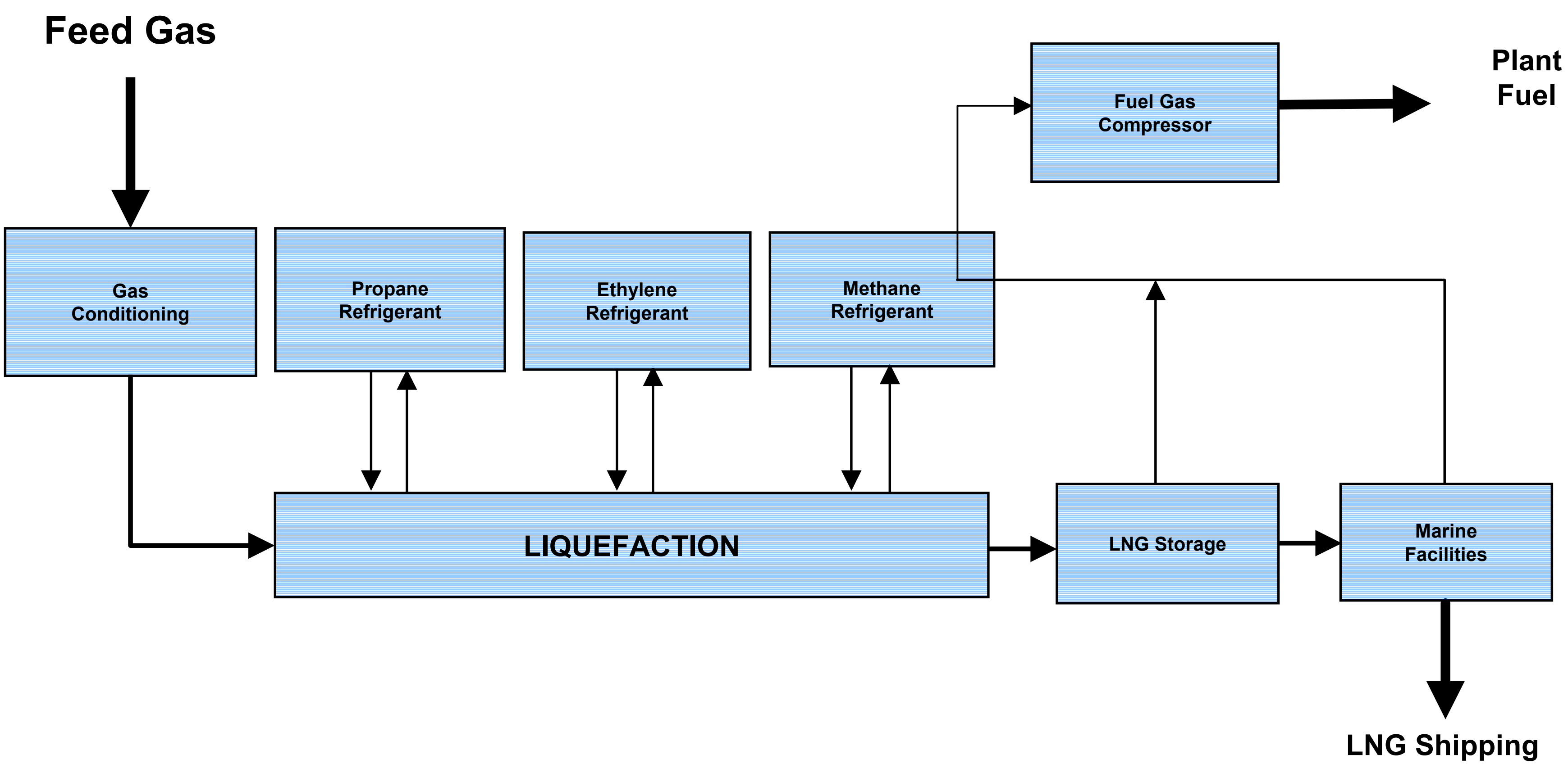
- Iterative Economic Solution
  - Multiple Options
  - Simultaneous Marketing Analysis
  - Environmental Impact Development
  - Mechanical Design Specifications
  - Equipment Vendor Alliances & Preferences
  - Management, Operations, Rotating Machinery Preferences
  - Schedule Changes

- Flexible & Economical Solutions Are Highly Desirable
  - Technology Licensor's Task is to Monitor and Anticipate Industry Needs and Develop Flexible & Competitive Solutions

Setting The Perspective

Historical & Current Overview of Technology In Consideration

Setting the Perspective
- Early Phillips Optimized Cascade Process -

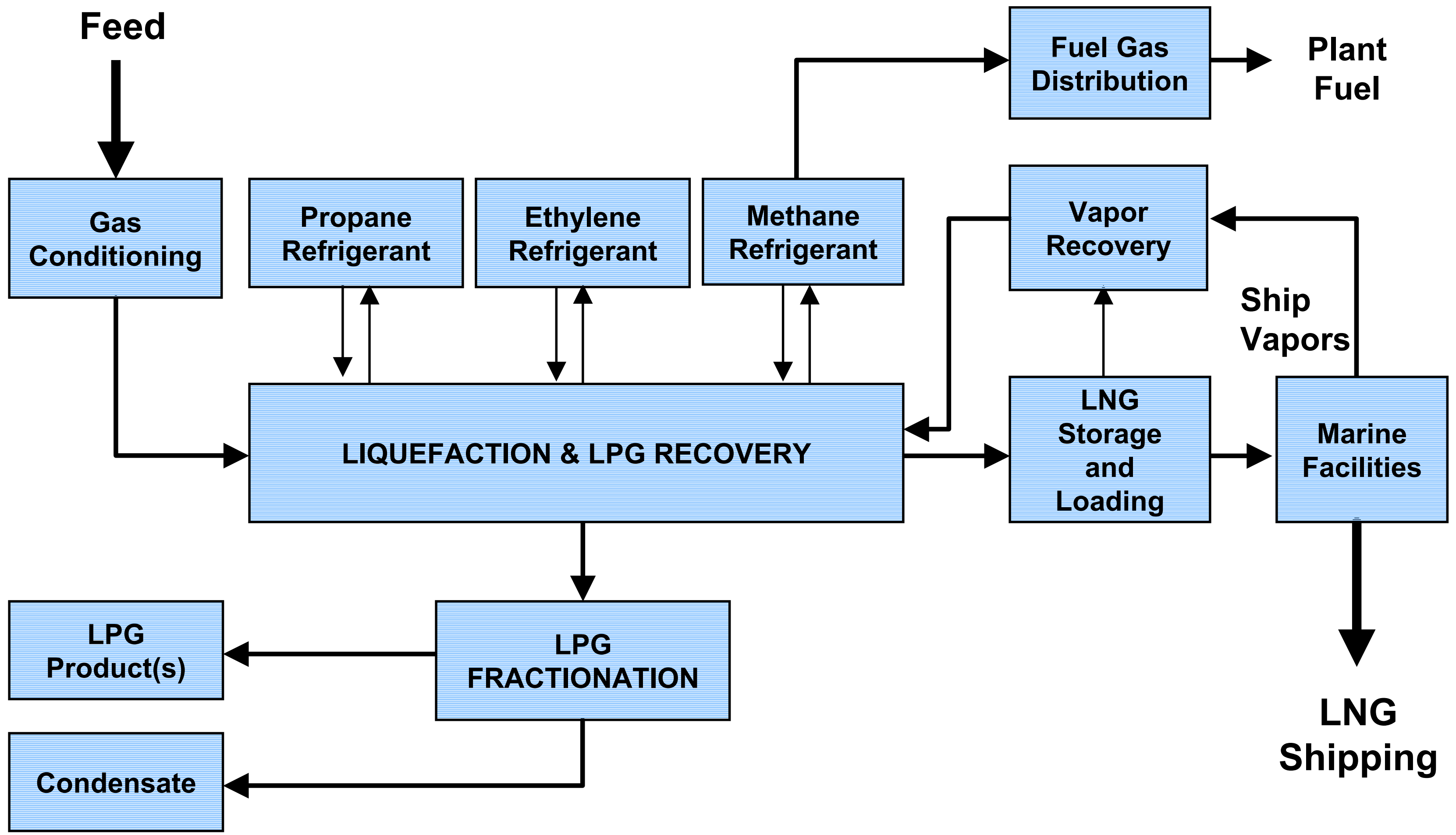


Setting The Perspective
- Kenai Alaska Facility -

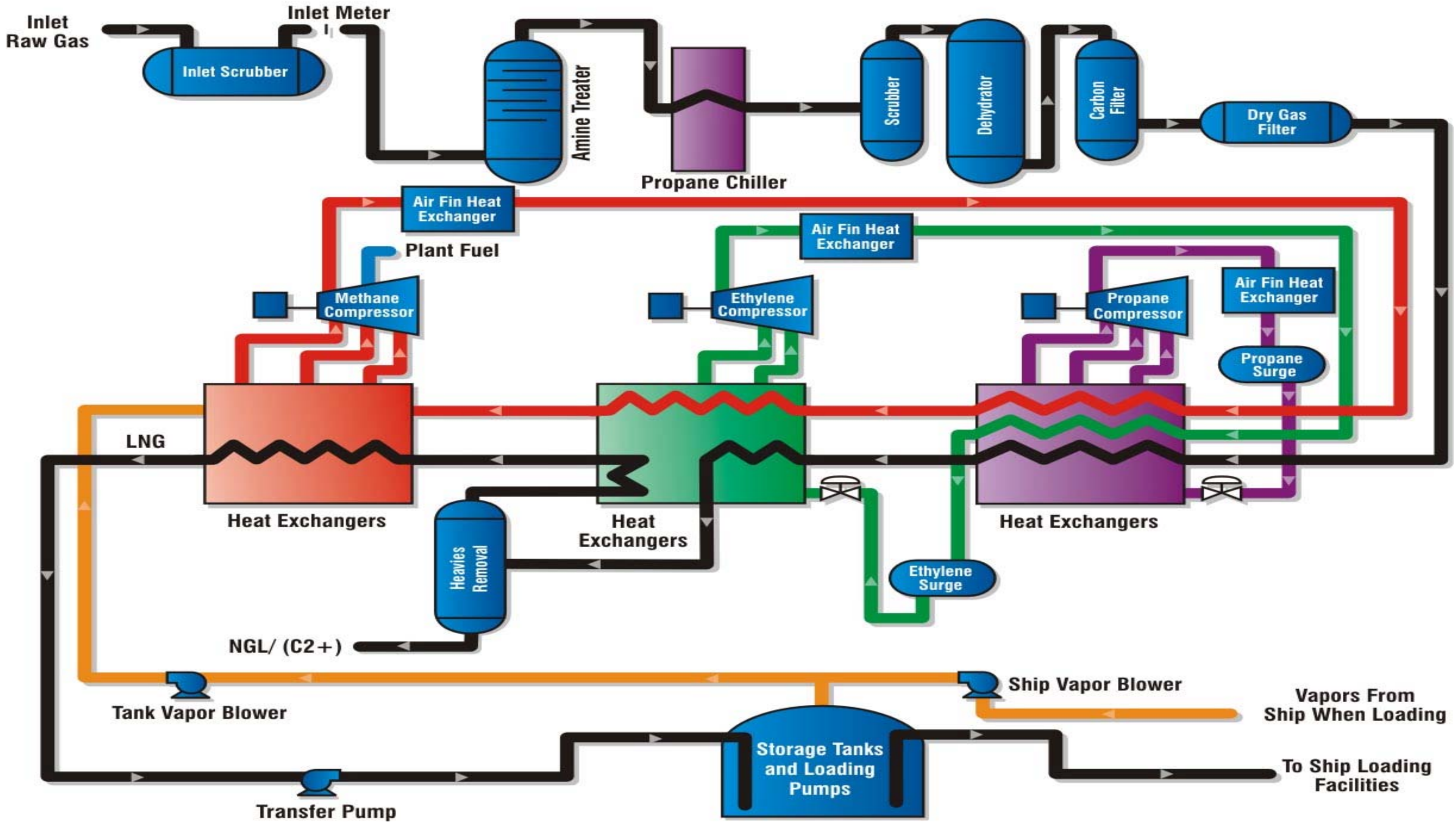
Setting The Perspective
- Improvements Over Early Design -

- Elimination of Fuel Gas Compression
- Heavies Removal Integration
- Improved Heat Integration
- Optimized Cold Box Configuration
- Improved Plant Layout and Constructability
- Open Loop Methane Cycle
  - Reduction in Vessels & Exchangers
  - Balanced Power Requirements Between Refrigerant Cycles
  - Optimal Compressor Staging

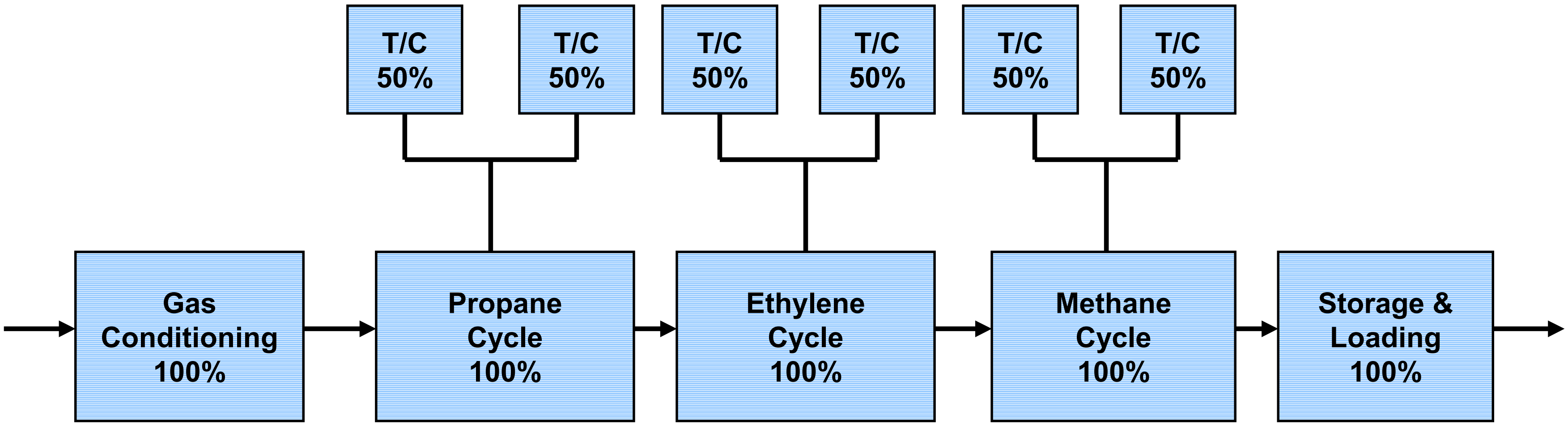
Setting The Perspective
- Current Simplified Block Flow Schematic -



Setting The Perspective
- Phillips Optimized Cascade LNG Process -



Setting The Perspective
- Simplified Driver Configuration -



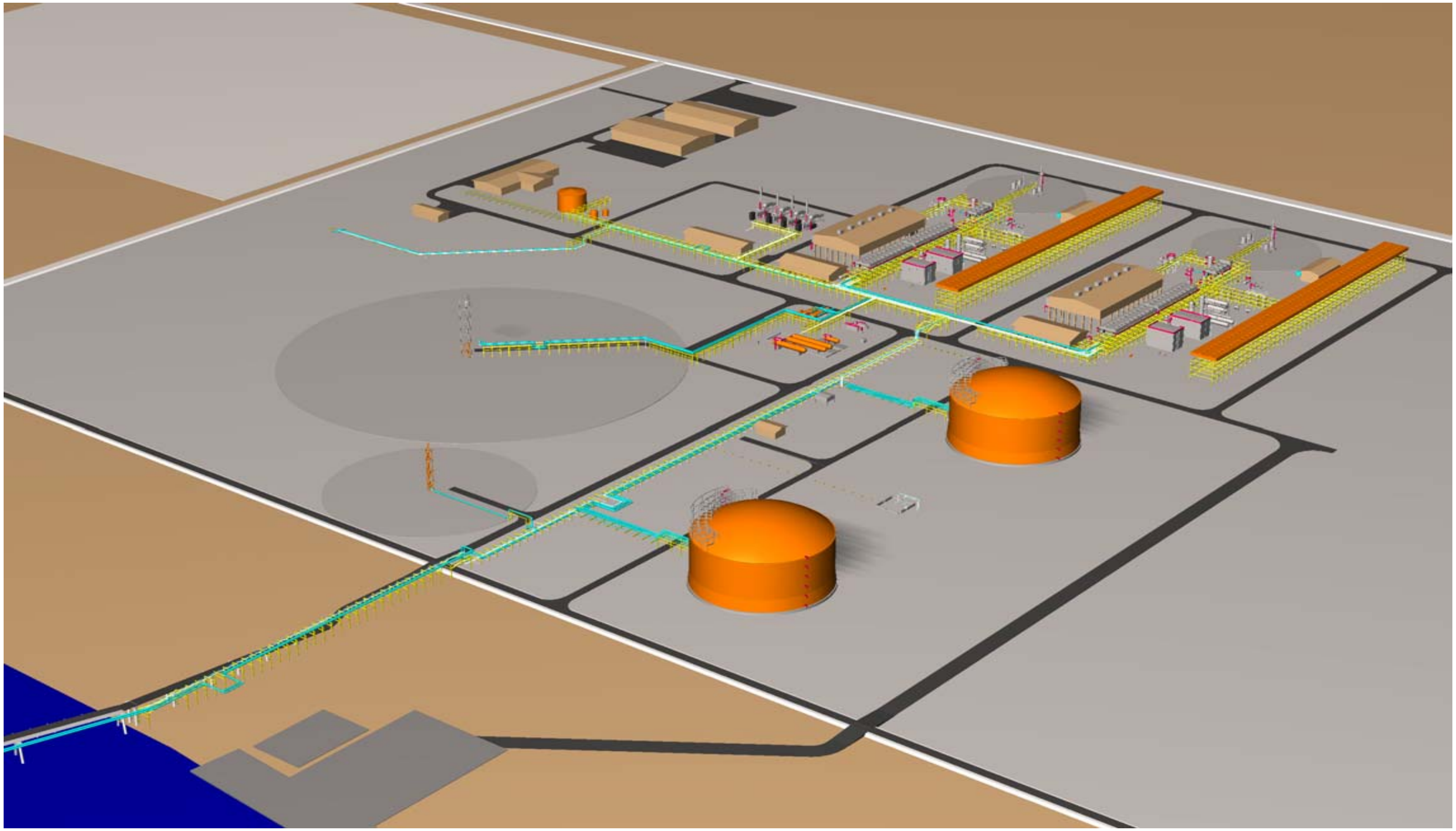
- Overall Plant Availability — >95%
  - Kenai – Over 33 Years Operation
  - Atlantic – Over 4 Years Operation
- Operational Flexibility — 0 – 105%
  - Full Rate — 80 - 105%
  - One T/C Down — 60 – 80%
  - Half Rate — 30 – 60%
  - Idle — 0 – 30%

Setting The Perspective
- Typical Balancing Act Results -

- CAPEX
  - Grass Roots ~ $200-250/MTPA
  - Multiple Trains < $200/MTPA
  - < 3% Contract Variations
  - Under Budget
- Schedule
  - All Projects Ahead of EPC Schedule
- Thermal Efficiency
  - Up to and Over 93%
- Availability
  - ~ 98% and Over
- Production Efficiency
  - ~ 95% and Over
- Capacity Factor
  - > 1 (Achieved Production > Design Production)

Setting The Perspective
- Atlantic LNG Facilities -

Setting The Perspective - Egyptian LNG Project -

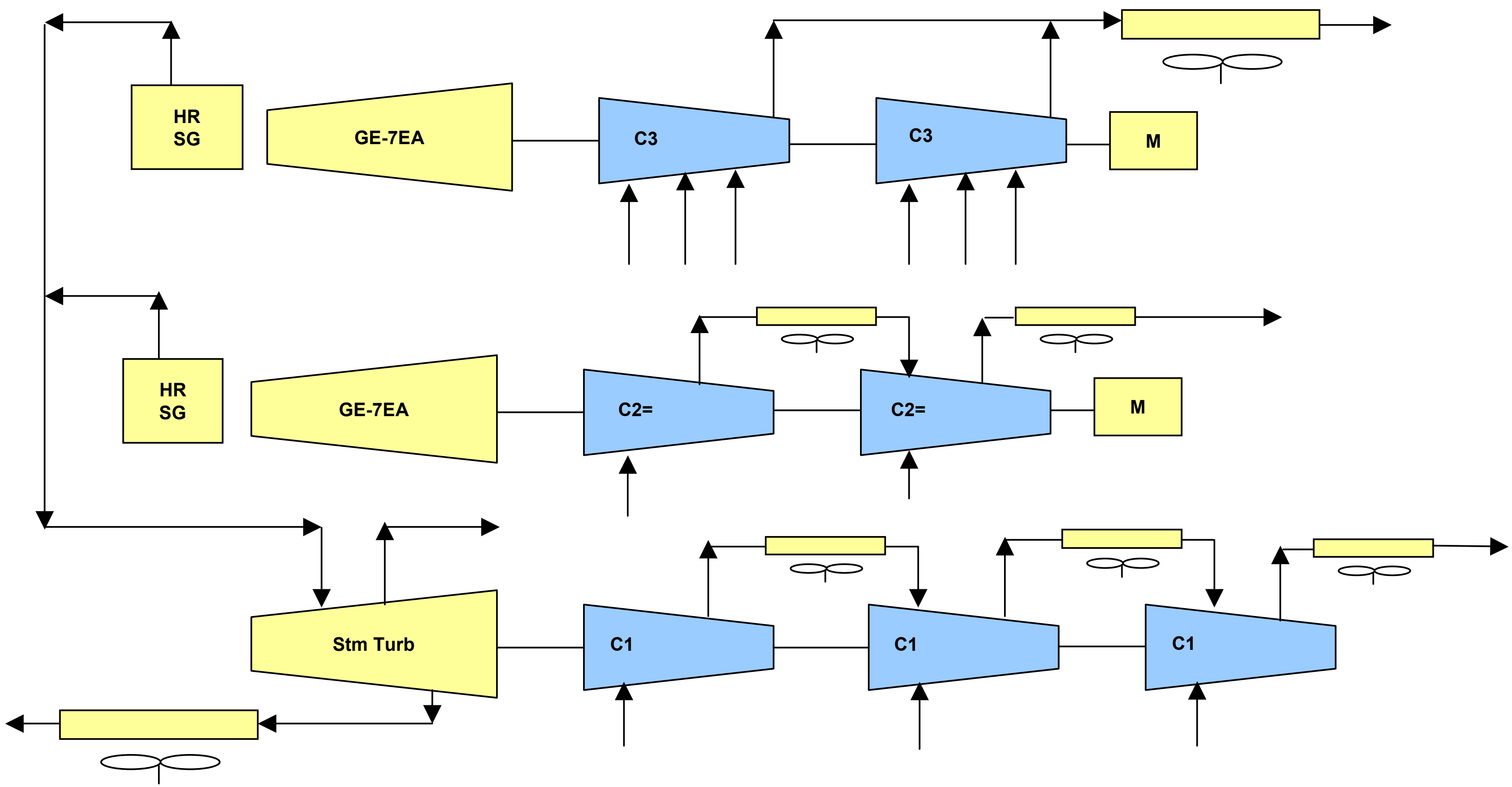


Setting The Perspective
- Darwin LNG Project -

An Alternate Approach

Minimize Gas Turbines and Integrate Waste Heat Recovery

An Alternate Approach
- Single Turbines & Waste Heat Recovery -



An Alternate Approach
- Basis For Study -

- Study Performed Using PDC
  - LNG Product Development Center

- Base Case
  - Atlantic Train 2 Conditions
  - Feed and Ambient Conditions Fairly Typical

- Multiple Driver/Compressor Configurations
  - Compared Against Base Case

An Alternate Approach
- Balancing Act Result Positives -

- **CAPEX**
  - ~ $200/MTPA (For Case Studied)
- **Schedule**
  - Assume Accurate EPC Schedule
- **Thermal Efficiency**
  - 93+%
- **Production Efficiency**
  - ~ 93%
- **Capacity Factor**
  - Assume > 1 (Predicted Production > Design Production)

An Alternate Approach - Balancing Act Result Negatives -

- Decreased Process Flexibility
  - No Two-Train-In-One Reliability
  - Complicated Steam System
  - Single Shaft Turbines
    - Loss of Speed Control
    - Longer Startup Sequence
    - Low Compressor Case Pressure Required for Startup

- Note 1: Supplemental power held at only that necessary to overcome compressor system starting torque requirements.

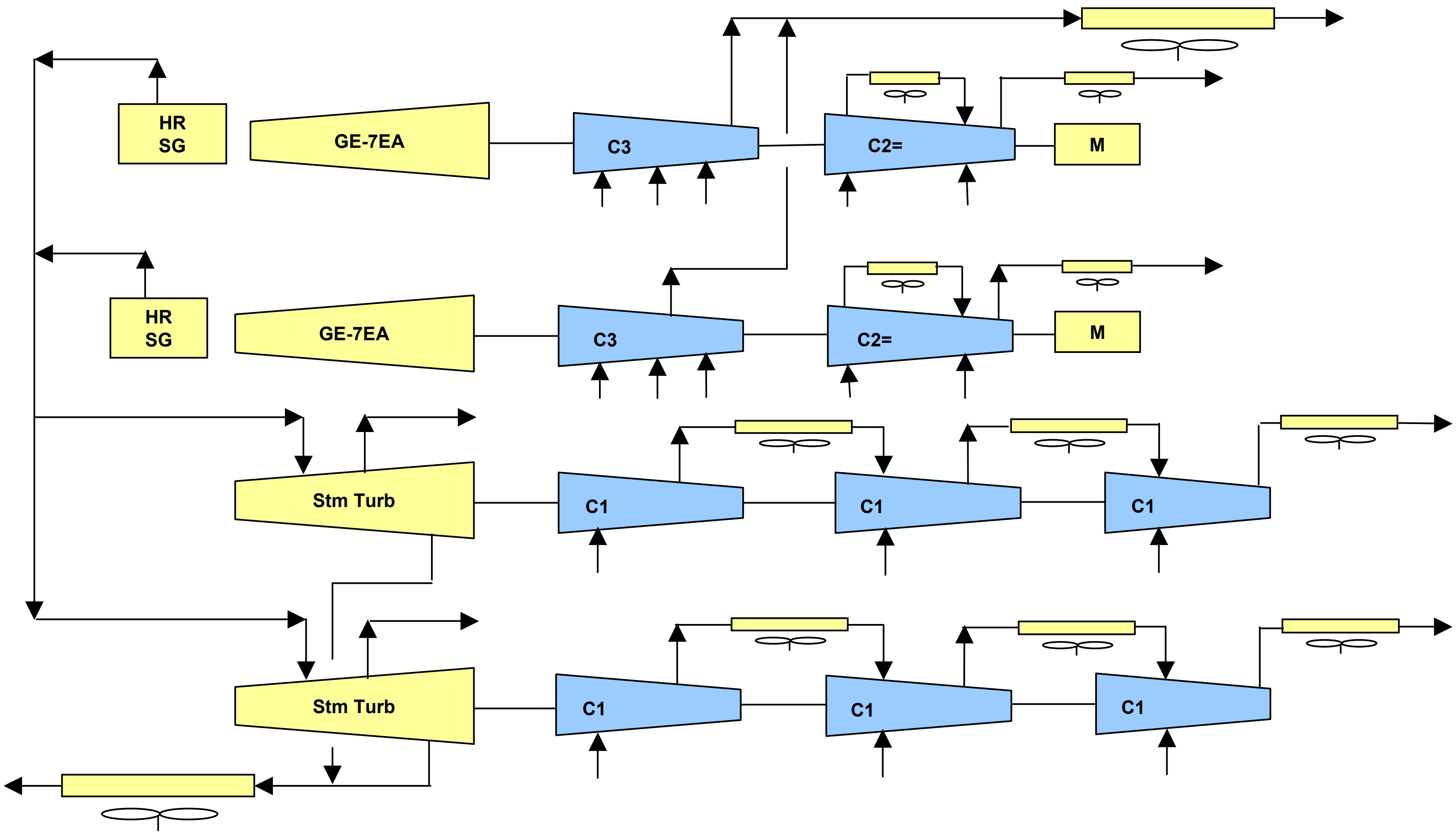
- Note 2: No vapor or liquid expanders included anywhere in the facility.

Furthering The Approach

Rebalancing the Variables

Minimize Gas Turbines, Integrate Waste Heat Recovery & Maintain Historical “Two-Train-In-One” Reliability

Furthering The Approach
- Add "Two Train In One" Reliability -



Furthering The Approach - Balancing Act Result Positives -

- CAPEX
  - Marginal Increase over Alternate Approach Above
  - ~ $200/MTPA (For Case Studied)
  - ~ 16% Decrease on TDC Basis From Base Case
- Schedule
  - Assume Accurate EPC Schedule
- Thermal Efficiency
  - 93+%
- Production Efficiency
  - ~ 95% ← As Compared to ~ 93%
- Capacity Factor
  - Assume > 1 (Predicted Production > Design Production)

Furthering The Approach - Balancing Act Result Negatives -

- Decreased Flexibility Over Multiple Dual Shaft Turbine Designs
  - Complicated Steam System But With Higher Reliability
  - Single Shaft Turbines
    - Loss of Speed Control
    - Longer Startup Sequence
    - Low Compressor Case Pressure Required for Startup

- Note 1: Supplemental power held at only that necessary to overcome compressor system starting torque requirements.

- Note 2: No vapor or liquid expanders included anywhere in the facility.

Conclusions

- **Cost Competitive, Flexible Solution With Waste Heat Integration**

- **Configuration Using GE Frame 7EA's**
  - **For Feed Conditions Considered, Applicable From 3.5 to 5.5 MTPA**
    - No Power Augmentation Other Than Starting Torque Requirements Considered & No Vapor Or Liquid Expanders Considered.

- **Configuration Using GE Frame 9E's**
  - **For Feed Conditions Considered, Applicable Up to 6.5+ MTPA**
    - No Power Augmentation Other Than Starting Torque Requirements Considered & No Vapor Or Liquid Expanders Considered.

Conclusions - Continued

- Environmentally Friendly Option
  - Less Point Sources for Emissions
  - Recovery of Thermal Energy
- Advantages Over Cogeneration Options
  - Large Electrical Motors Are Not Required
  - No Complicated Electrical Distribution
  - Power Directly Coupled to Refrigeration Shaft
- Easily Expandable Configuration
  - Example: Three Gas Turbines With Three or Perhaps Two Larger Steam Turbines

THANK YOU