Enhanced Reliability, Efficiency and Availability

Enhanced Reliability, Efficiency, and Availability LNG Facilities

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Presentation Agenda

- Introduction
  - Increased Importance of Reliability
  - Important Applications & Project Timing
- Definition of Terms
  - Availability
  - Production Efficiency
- Reliable Configurations
  - Review of “Two-Trains-In-One” Concept
  - Large Train Configurations
- Study Premises
- Cases Considered
- Study Results
- Conclusions

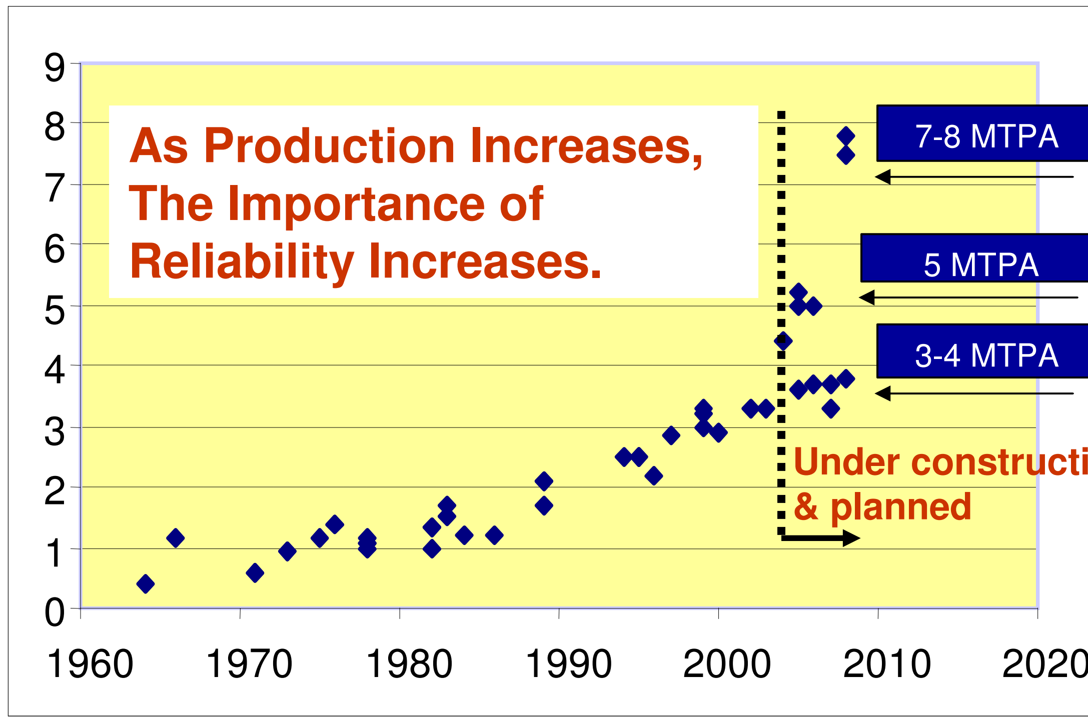
Introduction

RAM = Reliability, Availability and Maintainability

Historical Approach:

1) Minimum of 93% Availability Premised at Beginning of FEED.

2) Verified by Independent Third Party Near End of FEED.



Importance & Timing of RAM Analysis

- **Important Applications**
  - Life Cycle Cost Analysis
  - Technology Selection
  - Selection of Options Within a Given Technology
  - Critical Equipment Sparing Philosophy
  - Performance Comparison – Operational Facility
- **Project Timing**
  - Beginning of FEED – Technology Selection
  - Selected Cases Throughout FEED
  - Update at end of FEED
  - Critical Equipment Sparing Philosophy

Availability Definition

$$(1) \quad \text{Availability} = \frac{\text{MTTF}}{(\text{MTTF} + \text{MTTR} + \text{Mean Logistics Delay})}$$

- **MTTF = Mean Time To Failure.**
- **MTTR = Mean Time to Repair**
- **Mean Logistics Delay = Mean time required to assemble necessary items to perform repair, such as manpower, tools, parts, etc.**

Performance Based Metric

$$(2) \quad \text{Production Efficiency} = \frac{\text{Predicted Achieved Production}}{\text{Potential Production}}$$

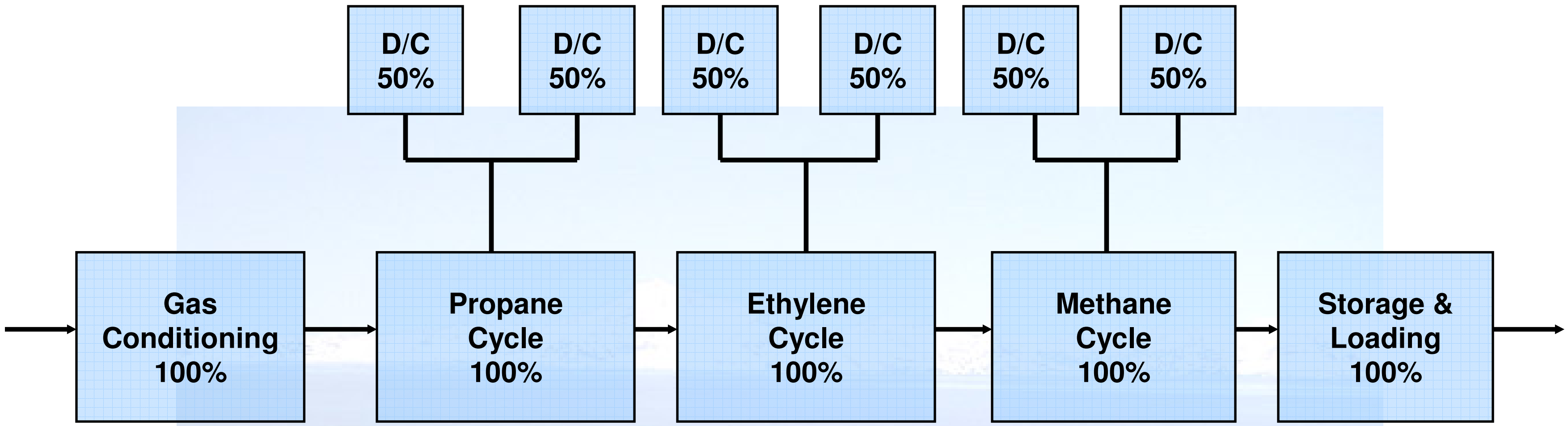
- **Predicted Achieved Production = Total field life production as predicted by the RAM model, while taking all production critical factors into account.**
- **Potential Production = Field life production as determined by deliverability profile for the system.**

Production Efficiency and Thermal Efficiency are Equally Important

Traditional "Two-Trains-In-One" Concept

Kenai Alaska LNG Plant

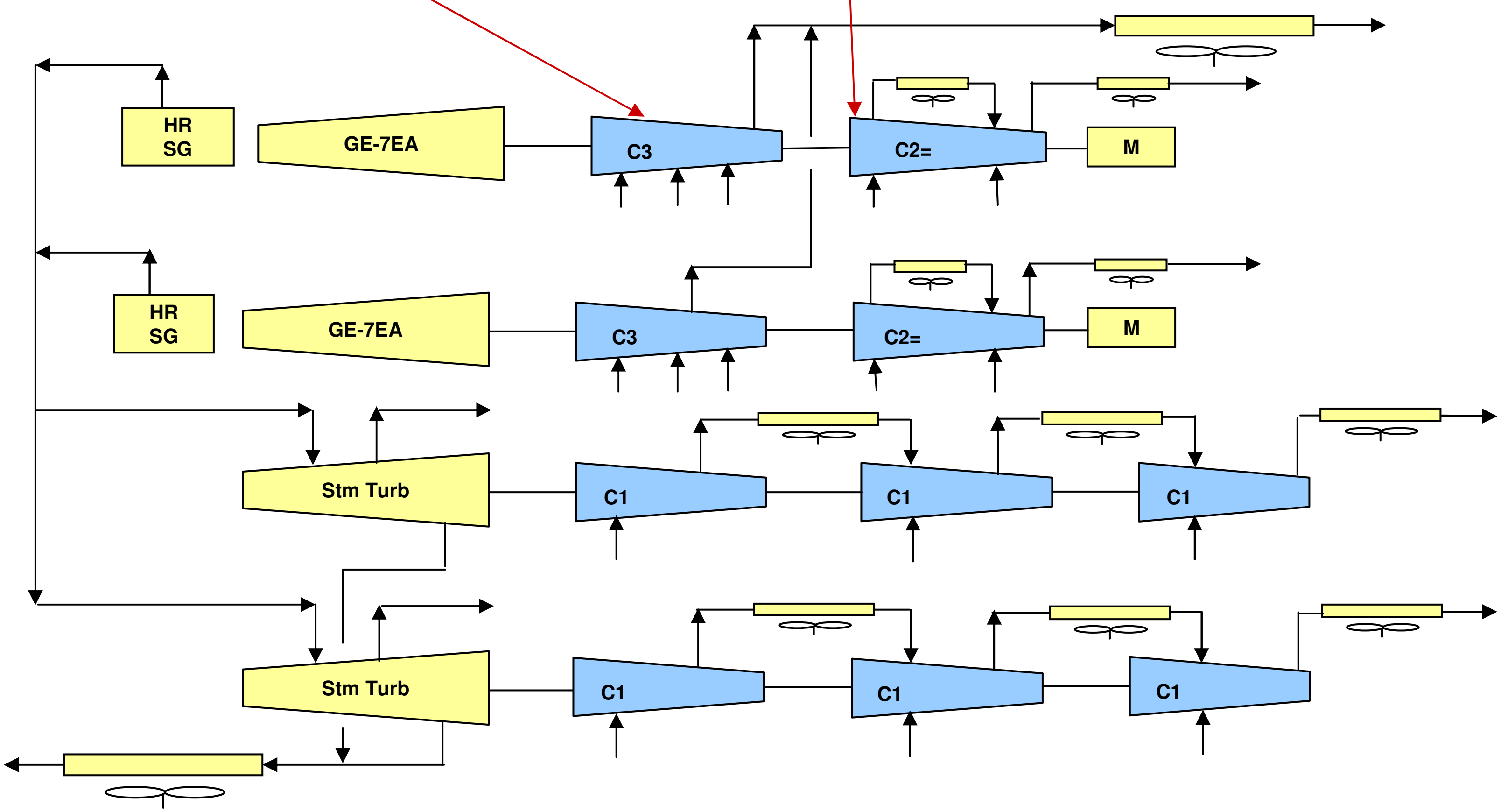
Traditional "Two-Trains-In-One" Concept



- Overall Plant Availability >98%
  - Kenai – Over 35 Years Operation
- Operational Flexibility 0 – 105%
  - Full Rate 80 - 105%
  - One D/C Down 60 – 80%
  - Half Rate 30 – 60%
  - Idle 0 – 30%

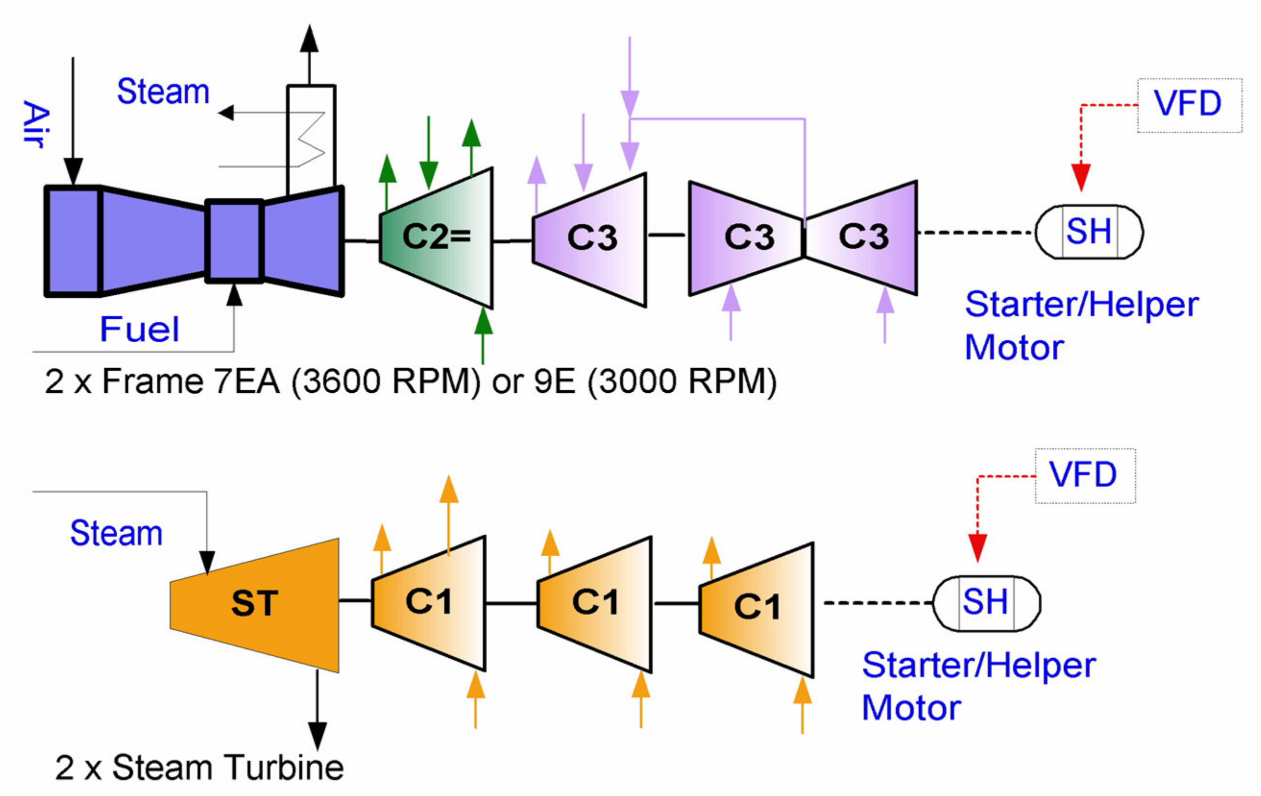
Large Train – GE-7EA or 9E W/ Waste Heat Recovery "Two-Trains-In-One" Approach

Propane & Ethylene Refrigeration Compressors On Same Shaft



Turbine/Compressor Configuration "Two-Trains-In-One" Approach

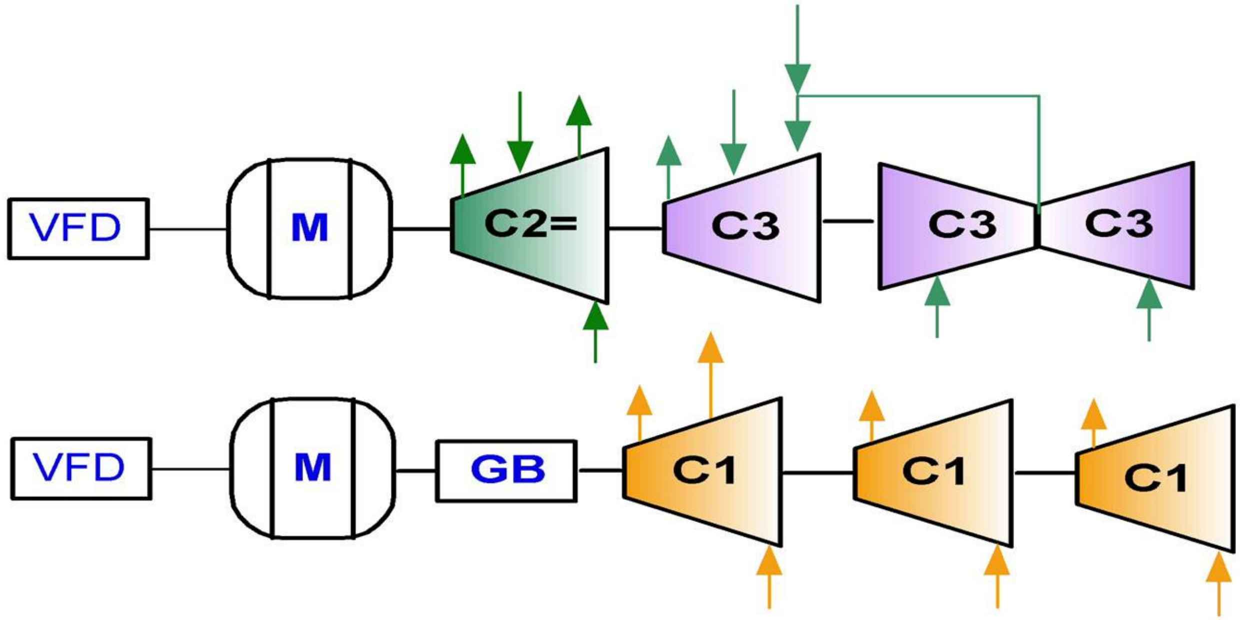
Configuration with C2=/C3 on the same driver shaft



2x Steam Turbine (or 1 Steam Turbine)

Motor/Compressor Configuration
"Two-Trains-In-One" Approach

Plant Capacity: Up to 8.0 mtpa



2 x 50% Configuration

RAM Premises

- Reputable, Independent Third Party to Perform RAM Analysis
  - Jardine & Associates, recently acquired by Detnorske Veritas
- MTTF & MTTR data in third party data base used without modification
- Scheduled maintenance fully verified through vendor data and recommendations
- Startup, ramp-up and chilldown times fully credible and physically demonstrated where possible, all falling within equipment specifications

RAM Premises - Continued

- For “Two-Trains-In-One” designs, detailed simulations utilized to provide production when one or more drivers are offline

- No credit taken for potential production in excess of equipment design margins.

- No scheduled downtime assumed outside of normally scheduled maintenance requirements such as for state or country required shutdowns for internal inspections

RAM Case Studies

Case ID	Configuration Description	"Two-Trains-In-One" Design (Yes/No)
Base	6 GE Frame 5D Turbines with parallel turbines on each of propane, ethylene and methane cycles.	Yes
1	2 GE Frame 7EA w/ propane and ethylene cycles on the same shaft and Variable Frequency Helper Motors. Waste heat recovery used to power parallel steam turbines on the methane refrigerant cycle.	Yes
2	3 GE Frame 7EA w/ Variable Frequency Helper Motors. One GE Frame 7 on each of propane, ethylene and methane refrigerant cycles.	No
2A	2 GE Frame 7EA w/ with propane and ethylene on same shaft and variable frequency drive helper motors. 1 Frame 7EA on methane refrigerant cycle.	Partial (Plant down if methane turbine offline)

RAM Case Studies – Cont'd

Case ID	Configuration Description	"Two-Trains-In-One" Design (Yes/No)
Base	6 GE Frame 5D Turbines with parallel turbines on each of propane, ethylene and methane cycles.	Yes
3	2 GE Frame 9E w/ propane and ethylene cycles on same shaft and variable frequency drive helper motors. Waste heat recovery used to power parallel steam turbines on methane cycle.	Yes
3A	2 GE Frame 9E with propane and ethylene on same shaft and variable frequency drive helper motors. Parallel electric motors on methane cycle with 2 Frame 9E in power generation service.	Yes

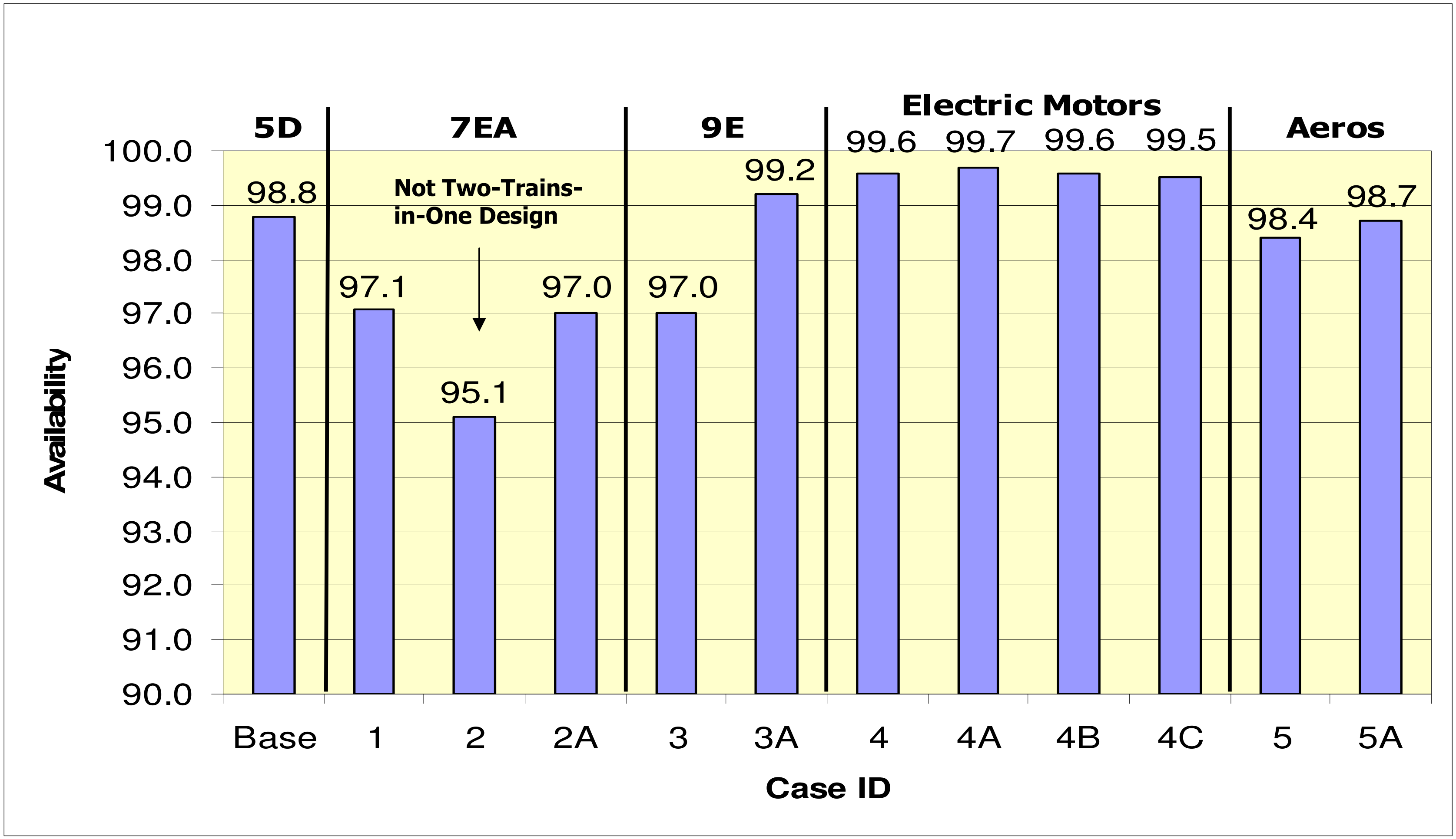
RAM Case Studies – Cont'd

Case ID	Configuration Description	"Two-Trains-In-One" Design (Yes/No)
Base	6 GE Frame 5D Turbines with parallel turbines on each of propane, ethylene and methane cycles.	Yes
4	3 full VFD electric motors on each of propane, ethylene and methane refrigeration cycles. Power taken from grid.	No
4A	2 full VFD electric motors with propane and ethylene cycles on the same shaft. 2 full VFD electric motors on methane refrigerant cycle. Power taken from grid.	Yes
4B	2 full VFD electric motors with propane and ethylene cycles on same shaft. 2 full VFD electric motors on methane refrigerant cycle. N+1 power generation for the facility.	Yes
4C	2 electric motors with propane and ethylene on same shaft and startup only VFDs. 2 electric motors on methane refrigerant cycle with startup only VFD. N+0 power generation for the facility.	Yes

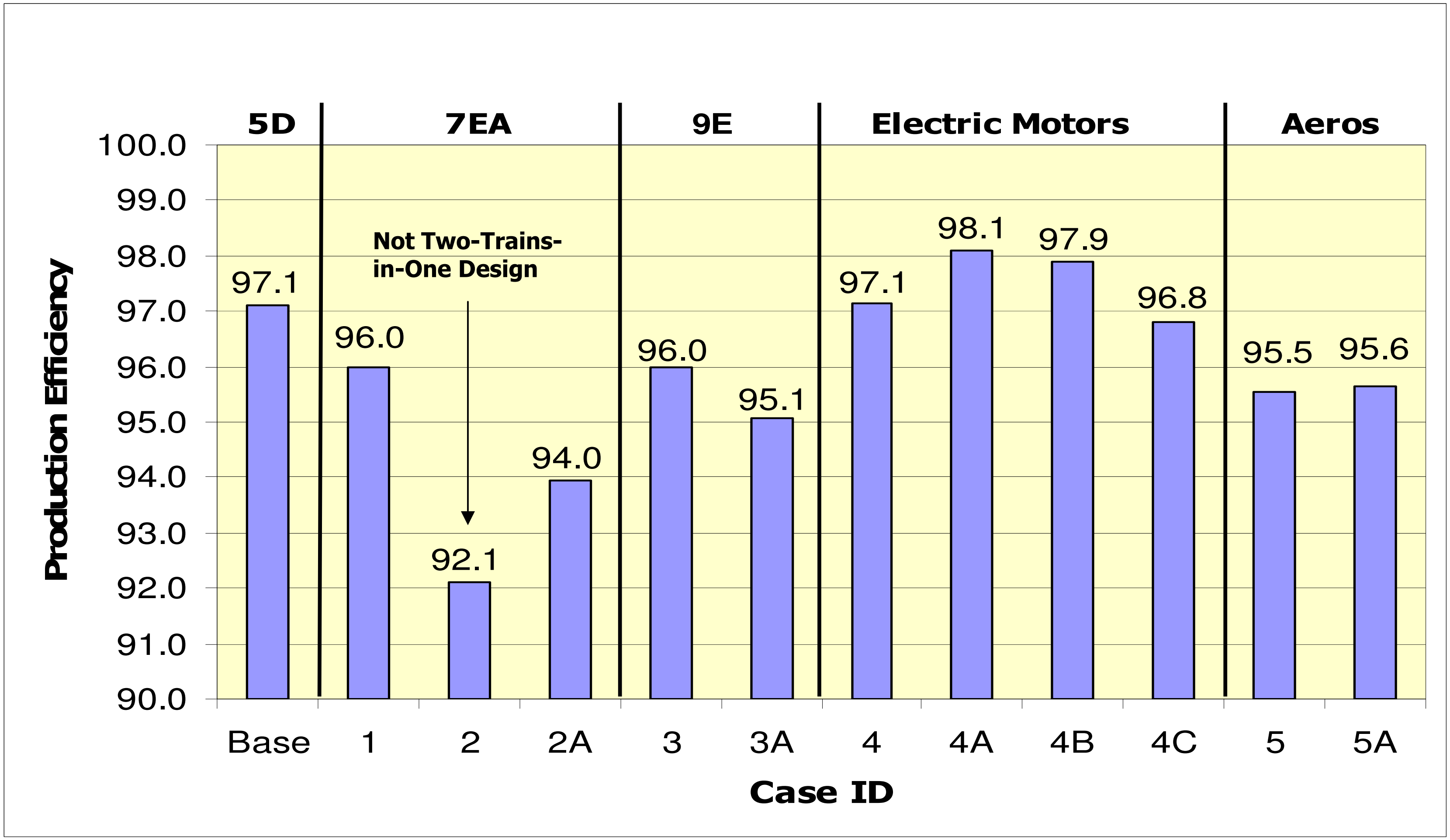
RAM Case Studies – Cont'd

Case ID	Configuration Description	"Two-Trains-In-One" Design (Yes/No)
Base	6 GE Frame 5D Turbines with parallel turbines on each of propane, ethylene and methane cycles.	Yes
5	6 Rolls Royce Trents DLE (Aeroderivative) with parallel turbines on each of propane, ethylene and methane cycles.	Yes
5A	6 GE LM-6000 (Aeroderivative) with parallel turbines on each of propane, ethylene and methane cycles.	Yes

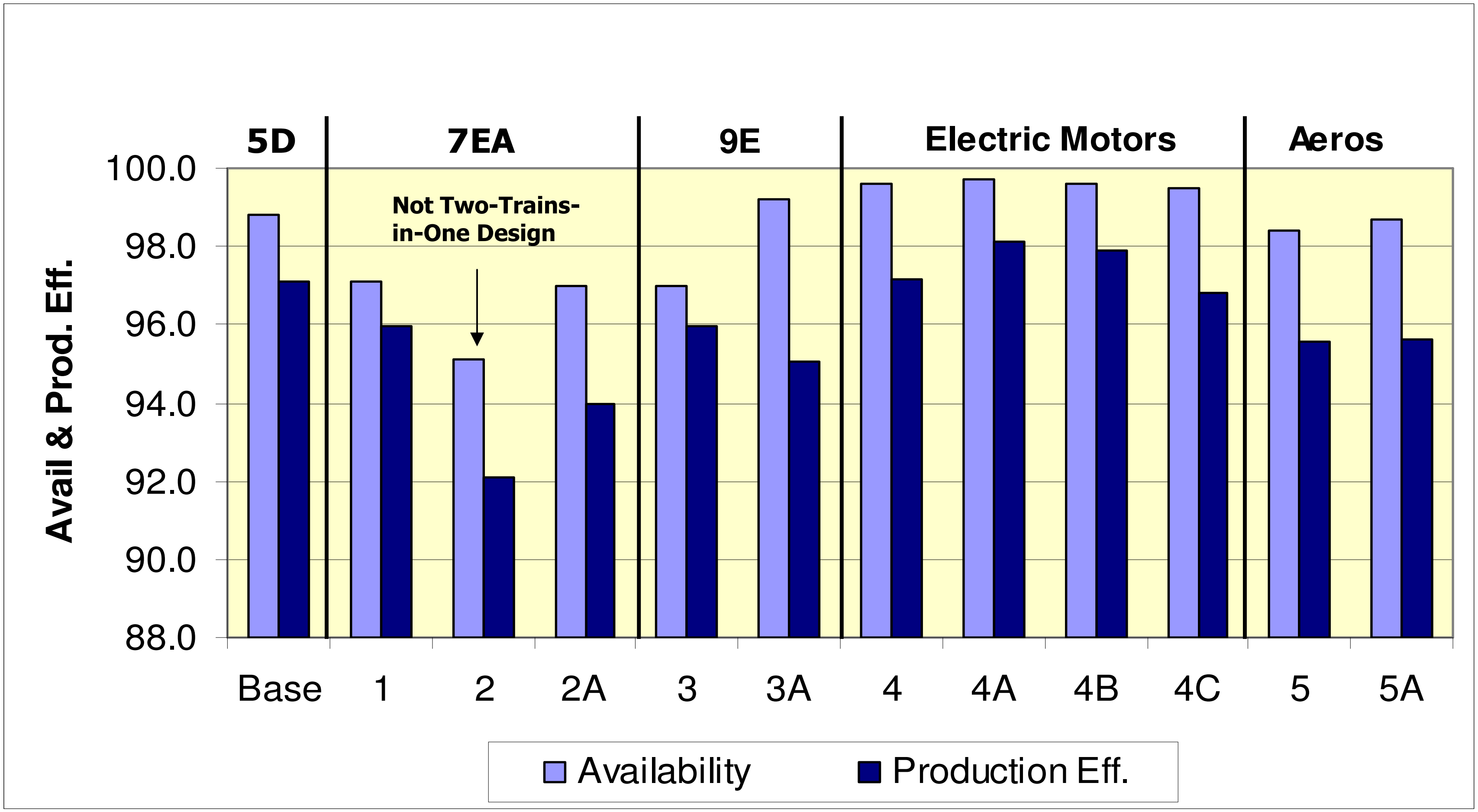
Case Study Availability Results



Case Study Production Efficiency Results



Comparison of Availability & Production Efficiency



Conclusions

- A Thorough and Accurate RAM is an Invaluable Tool Throughout All Phases of a LNG Project.
- A RAM Analysis Should Begin Early in FEED or Pre-FEED Process and be Utilized Well After Startup
- Production Efficiency Should be Utilized for Life Cycle Cost Analysis – Not Availability
- Production Efficiency and Thermal Efficiency Should be Given Equal Importance
- With Typical Production Efficiencies Ranging From 94 to 97% and Higher, the CoP LNG Process Offers an Attractive LNG Solution

THANK YOU