RAM Modeling Defined
Using Titan™ System Performance Software

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Executive Summary
This document was prepared by The Fidelis Group, LLC and is intended to inform and educate the reader on the concept of RAM Modeling and the uses of RAM Modeling software.

Key Definitions
RAM Modeling includes the following components:

1. **Reliability** – is the probability that an item will perform its intended function for a specified interval under stated conditions.
   \[ R(t) = e^{-\lambda t} \quad \text{where} \ t = \text{time}, \ \lambda = \text{failure rate (1/MTBF)} \]

2. **Availability** – is defined as the total time a system is in an operative state. For example, if a chemical plant ran for 95% of the total time in one year, the uptime or availability would be 95% for this year.

3. **Maintainability** – is defined as the ability of an item to be retained or restored to specified conditions when maintenance is performed by qualified personnel. For example, when you take your car in to be serviced, will the repair make your engine like new (new parts) or just bring it back to a bit newer than the current state (change oil)?

When the three key terms are combined, RAM Modeling Software is used to create a computerized simulation of a complex processing system. The specific software that The Fidelis Group, LLC designed and utilizes is Titan™ RAM Modeling Software.

**Titan™ RAM Modeling**
Titan™ is unique among stochastic or dynamic RAM simulation tools in its ability to handle all of the complexities that typically arise in the process plant environment, thereby generating more accurate and profitable outputs. During the design/acquisition phase, RAM Modeling can help guide the development and design of new systems. The insights provided by RAM Modeling can help companies avoid issues before they happen - saving time and money. Once a system is running (in-service phase), there is the potential for improvement. How much improvement and what kind of improvements are questions which RAM Modeling can help answer.
Introduction & Objectives of RAM Modeling

This document was prepared by The Fidelis Group, LLC and is intended to inform and educate the reader on the concept of RAM Modeling and the uses of RAM Modeling. Specifically, The Fidelis Group designs, licenses and utilizes Titan™ RAM Modeling Software to produce discrete-event envelope studies that enables our clients and users to determine the reliability and key contributors to losses expected over time.

Reliability Defined

Reliability – is the probability that an item will perform its intended function for a specified interval under stated conditions.

\[ R(t) = e^{-\lambda t} \quad \text{where} \ t = \text{time}, \ \lambda = \text{failure rate} \ (1/\text{MTBF}) \]

For example, what is the probability that P-101 with a failure rate of .001 \ (\text{MTBF} = 1000 \text{ hours}) will operate for 500 hours without fail?

\[ R(500) = e^{-0.001(500)} = 0.6065 = 61\% \]

Availability Defined

Availability – is defined as the total time a system is in an operative state. For example, if a chemical plant ran for 95% of the total time in one year, the uptime or availability would be 95% for this year.

Maintainability Defined

Maintainability – is defined as the ability of an item to be retained or restored to specified conditions when maintenance is performed by qualified personnel. For example, when you take your car in to be serviced, will the repair make your engine like new (new parts) or just bring it back to a bit newer than the current state (change oil)?

When the three key terms are combined, RAM Modeling Software is used to create a computerized simulation of a complex processing system. The specific software that The Fidelis Group, LLC designed and utilizes is Titan™ RAM Modeling Software.
**Titan™ RAM Modeling Software**

Titan™ is unique among stochastic or dynamic RAM simulation tools in its ability to handle all of the complexities that typically arise in the process plant environment, thereby generating more accurate and profitable outputs. Some of the features include:

- Handling of multiple flows
- Handling of reduced and turn-up flow scenarios
- Handling of pooled spare parts
- Integrated spare parts optimization engine
- Handling of storage tanks (feed, intermediate and product)
- Handling of complex tank logic
- The ability to input any kind of complex operating, maintenance or logistics logic through a custom Microsoft VBA interface
- Speedier simulation times due to state of the art software coding
- Animated simulation to easily validate complex models
- Default outputs tailored to the process industries
- Easy to use Graphical User Interface
- Interfaces with external databases (CMMS, Excel, LP models, etc)

Titan™ RAM Modeling utilizes a Monte Carlo engine in order to simulate all of the probable future performance metrics of a given design. The output is used to quantify the economics of equipment related decisions such as redundancy, spare parts, equipment sizing, maintenance practices and policies, quality of component, etc.

A sensitivity list quantifies the contribution of each component in the model to non-performance allowing the user to optimize the design for lowest life-cycle cost.

**RAM Modeling General Approach**

The Project Modeling Team will conduct the analysis as follows:

1. Create a predictive model of the processing site using system logic, configuration information, PFD’s and P&ID’s.
2. Use unit and equipment reliability information and repair and maintenance data from the project team, industry databases, and Fidelis Group, LLC reliability database.
3. Validate the reliability model performance and data assumptions with the project team.
4. Explore the impact on system reliability for the base case model and alternative studies.
5. Communicate results orally and in a written report.
The Titan™ RAM model was run for many life-cycles of 10-30 years each. Each of the RAM modeling runs is a possible future performance of the processing System. Statistics are kept for each life-cycle and aggregated at the end of the simulation to provide probabilistic outputs – expected system behavior and the variation possible in the behavior.

In general, Titan™ and other Monte Carlo discrete-event simulation programs utilize statistical sampling techniques in order to predict future performance of a system. The behavior of components in the system (pumps, motors, reactors, etc.) is represented by a probabilistic distribution function. This function is derived by using curve fitting techniques on the raw data. Raw data is simply intervals between failures and repairs. The curve that is generated represents the possible failure or repair behavior of the component. Titan™ samples from this curve and derives a time to failure or repair for each piece of equipment. Many life-cycles are run in order to sample enough points from all of the components in the model to insure that all possible combinations are taken into account.

Each life-cycle is a possible future life of the actual system. After many life-cycles, a histogram of the possible outputs is created. In this way, the results have a confidence or probability attached to them-not just an average or mean.

As each component fails, it has an effect on the unit that it is in which in turn has an effect on the flow sent through the pipes attached to that unit both upstream and downstream. Titan™ tracks the flow through the pipes as well as the utilized and available capacities of the units.

This study began with an “as-is” model of the system. A project flow diagram, asset register (list of equipment and their failure and repair distributions), and operating rules were constructed for the model. Input data supplied by the team was incorporated into the model.

Inputs:

- System configuration diagrams
- Equipment list
- Impact of component failures
- Operating rules
- Equipment nominal and design capacities
Scope of RAM Modeling
The scope of the RAM Modeling effort is determined by the modeling objective. The size and scope of the modeling effort should only be as large as is required to meet the objective. In general, RAM Modeling includes all process critical equipment identified in the PFD’s or P&ID’s. For example, the model included all pumps, motors, blowers, reactor, and some critical instrumentation and valves. In addition, non-mechanical events such as weather, operator error, and preventative planned maintenance are included.

What can be simulated through RAM Modeling?

- Entire Supply Chain
- Process Site
- Process Units
- Sub-Systems

Within these modeling subsets, the user can include:

- Mechanical Equipment
- Fixed, Rotating, etc.
- Pipes
- Tanks
- Reactors
- Instruments
- Electrical Systems (switches, breakers, buss bars, etc.)
- Human Behavior
- Failure Modes
- Scheduled Activities
RAM Modeling Supply Chain

1. Ethylene Unit
   - C2 Storage
   - C3 Storage
   - Polypropylene Unit

2. Ethylene Import

3. Oxygen Plant
   - EO Unit
   - EO Storage
   - Polyurethanes Unit

4. Polyethylene Storage
   - Product A
     - Xfer A
   - Product B
     - Xfer B
   - Product C
     - Xfer C

5. Polyethylene Storage

6. C2 Storage

7. Polyethylene Unit

8. C3 Storage

9. Polypropylene Storage

Train Loading
Shipping
Demand
Uses and Benefits of RAM Modeling

During the design/acquisition phase, RAM Modeling can help guide the development and design of new systems. The insights provided by RAM Modeling, can help companies avoid issues before they happen - saving time and money. Once a system is running (in-service phase), there is the potential for improvement. How much improvement and what kind of improvements are questions which RAM Modeling can help answer. Here are some real life examples.

RAM Modeling - Oil Production

During the design phase, our RAM Modeling was used to determine if a single oil processing train versus a double oil processing train would perform more optimally. Design specification such as the size of each train, the quality of components and the amount of redundancy were considered. For example, would a single 1 x 100% redundancy train perform better than a 2 x 50% two-train oil processing configuration? With the alternate case results complete, the simulation provided the net change in revenue (or barrels per day). By comparing the revenue streams to the associated capital investments, this key design decision was an easy one.

On another design project, our RAM Modeling was used to determine if a company’s oil production should be sent for processing through a subsea tie-back for third party processing or if a standalone topside processing facility should be constructed. The cost delta between these two options was enormous, but the differences in expected profits provided quantitative answers for decisive decision support.

During the in-service phase, our RAM Modeling is most often used to identify and quantify facility bottlenecks. For many clients, this analysis becomes necessary either when actual oil, water and gas forecasts differ from expected estimates or perhaps when a field has reached reservoir maturity. When this occurs, the oil/water/gas ratios may change significantly which in turn constrains the facility. For these cases, our RAM Modeling has been used to identify these bottlenecks, quantify the effect on revenue and optimize the schedule for capital improvements, and evaluate difference capital improvement methodologies.
RAM Modeling - Refining

During the design phase, our RAM Modeling has been used to optimize unit redundancy needs, turn-up capacity, maintenance scheduling, spare parts quantities and intermediate buffering. To ensure that product demands are met, our RAM Modeling measured the net improvement of either changing compressor redundancy or train capacity. When our RAM Modeling Software completed several alternate simulations, varying each of these variables in turn, the overall refining capabilities improved and return on investment increased.

With refining, operating flexibility is very important. Our RAM Modeling has been used to increase operating flexibility and improve shipping logistics. In this industry, demand is variable and product profitability is dynamic. Given the current market conditions, our RAM Modeling Software was used to test the performance of several operating modes. RAM Model Software proved that small design improvements dramatically increased operating flexibility and the ability to change product mixes to maximize profitability. In addition, improved overall performance simplified logistics, maintenance, and decreased cost penalties associated with missed deliveries or vessel bunkering delays.

Once in operation, refining involves complex day to day decisions regarding optimal preventative planned maintenance and spare parts procurement decisions. For example, should a company allow equipment to run to failure or service proactively? Should a company have 1 spare part on the shelf or ten? Our RAM Modeling tool has been used to answer these questions and improve profitability by increasing refinery performance while optimizing spare parts inventory.

RAM Modeling - Chemical Processing

During the design phase of an integrated chemical processing facility, our RAM Modeling was used to determine the appropriate unit capacity, train redundancy, turn-up capability and quality of component. With the alternate case results complete, the simulation provided the optimal combination of all of these variables while ensuring that production targets were met. Given current market conditions and estimates, the engineering team was then able to use these production outputs to determine the life cycle cost benefits. For example, does the designed facility and expected production offer a fast enough return on investment to warrant further progress with this project? Capital Cost savings were measured in the 9 digit range.

During the design phase of a tightly integrated petrochemical site, the size and location of buffer volumes is instrumental. Our RAM Modeling was used to optimize overall site integration by introducing key buffer
volumes throughout the process and optimizing the size to decrease capital costs. For example, should your ethylene and propylene buffer tanks be larger or smaller? Are there additional intermediate product buffers needed to help mitigate downstream product losses?

Once in operation, optimizing preventative planned maintenance schedules and spare parts procurement decisions is very valuable. Our RAM Modeling tool was used to answer these questions and improve profitability by increasing site performance while optimizing spare parts inventory.

**RAM Modeling - Power/Cogen**

During the design phase of a power generation facility, our RAM Modeling was used to determine if a utility grid connection would provide adequate electrical reliability. This option was compared to one with self-generation. For these cases, the model determined that the utility grid did provide adequate reliability and that the additional cost of adding on-site generators was unnecessary. This proved to be a significant cost savings to the company.

When designing a new steam generation facility, our RAM Modeling was used to determine the size and optimal number of steam boilers. After running several alternate cases with many different size differentials and configurations, the model landed on the most economical design that would provide the required level of reliability. This could be completed for any utility plant such as air compression, power generation, co-generation, or even water supply & treatment.

During the operational phase of many utility plants, demands for electricity, stream, and instrument air often increase as the customer plants grow and increase production. Our RAM Modeling has been used to help evaluate many different de-bottleneck alternatives. When the desired reliability of each alternative is achieved, completing a cost analysis is an easy way to select the most economical solution. Some examples of this may include: selecting a vendor for a new skid, installing standby generation or diesel backups, connecting to a standby utility header or improving site recovery methods.

**RAM Modeling - Mining**

During the design phase of the project, our RAM Modeling was used to evaluate the project life cycle costs. The model was initially constructed at a high level, but added additional detail over many months as the design process moved forward. After each major design phase, the model was used to measure return on
investment. In this way, the project continued to prove its value and eventually moved into commissioning and start-up with an assurance of profitability.

Within a mining operation, meeting variable demands and allocating resources is a day-to-day challenge. To overcome these challenges, our RAM Modeling Software has been used as a day-to-day planning tool. Pulling from an expected demand schedule, the model was used to predict the level of human resources required and the equipment that would be needed to achieve production goals.

**RAM Modeling Software Screenshots**

![Titan™ RAM Modeling Software Control Panel](image-url)
Titan™ RAM Modeling Animation Screen

Titan™ RAM Modeling RAM Data Editor (imported directly from Excel)
Titan™ RAM Modeling Results – System Sensitivities

Titan™ RAM Modeling Results – Time based performance (Unit Availability)
Titan™ RAM Modeling Results – Probability to meet or exceed Histogram

Titan™ RAM Modeling Results – Sensitivity Summary
### Titan™ RAM Modeling Results – Unit Capacity Summary

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### Titan™ RAM Modeling Results – Unit Shutdown/Slowdown Summary

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General Disclaimer

This report and associated model files summarize the key terms and uses of RAM Modeling. The applicability and accuracy of the definitions reported herein are dependent upon the application of the key terms; this document is intended to aid in educating the audience about RAM Modeling.

No Third Party Beneficiaries: This report is intended for use solely by Fidelis Group, LLC for educational purposes. It may not be used or relied upon by anyone else. There are no Third Party Beneficiaries.