HOW TO OPTIMISE ALLOCATION SYSTEMS BY USING MONTE-CARLO SIMULATION

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1 Introduction

The present low Oil price is forcing all petrochemical operating companies to actively review and reduce expenditure whilst maintaining or increasing production, ensuring a healthy return on investment for the shareholders. This has generated the need for new and innovative approaches in the way we manage our business. By forming a common interest group between operating service companies ideas can be developed with more focus and put into practice quicker. The authors having formed such an alliance would like to demonstrate that, by application of system models utilising Monte Carlo Simulation (MCS), how the operator can focus his limited resources and budget in the areas of greatest sensitivity and where the biggest benefit can be gained.

This type of model is equally applicable to both old and new systems. By assessment of the impact of each node within a system, against the output requirements using the MCS modelling techniques, the importance and impact of each node can be established. For existing systems this allows the user to define whether the present operating conditions meet the applicable agreements: and if optimisation in areas can be made whilst still remaining within the terms of the relevant agreements. For new green field developments the uncertainty can quickly be determined, establishing the limits which can be achieved and hence equipment required. The biggest benefit is for new projects over existing facilities, the allocation possibilities can be tested and the best method found not only in exposure but also cost.

Combining the benefits of applying new technology and optimising the use of the available facilities can easily be determined at project definition stage. Making presentation to all concerned parties simple and clear; and decisions can consequently be made faster.

The application of MCS techniques and the availability of powerful desktop computers are the key elements to the underlying simplicity and reliability of this approach. Enabling the determination of the propagation of uncertainties of most simple and complex measurement systems including many which cannot be found readily by conventional analytical means.

A detailed description of the MCS technique as applied to uncertainty determination can be found in the paper "Uncertainty of Complex Systems by Monte-Carlo Simulation" [1].

2 APPLICATION POSSIBILITIES

When a new measurement station is built, an uncertainty calculation of the system should be carried out. These figures are intended to show any associated parties the systems maximum potential exposure at any given time, the limits of this figure are usually quoted in any legal agreement. If the new measurement point is entering an existing pipeline system then it will be expected to meet the same level of uncertainty budget as the other entrants into the system (this may be negotiable).

The initial intention of the MCS model was to ascertain the uncertainties of such a system. During the development of the model other uses started to materialise; and as more individuals interfaced with the product the application possibilities increased. Aspects of not just uncertainty percentages but actual production allocation and determination became viable, mis-measurement determination, facilities optimisation (enabling resource application to areas of greatest exposure) and future prospect potential determination. This type of model is now being taken forward with the intention of becoming a full operational tool. By taking the concept further, has allowed a full pipeline system model to be developed giving a higher level overview of exposure for all partners.

The conceptual stage of a project, looking at existing facilities and new tie back wells can be reduced. By quickly determining the best overall usage of the existing facilities against the available and proposed flow regimes under the conditions prevailing or envisaged. Thus making the determination of whether it’s a viable proposal or not at an earlier stage, or in fact that by changing the present regime of operating scenarios other previously discarded ventures may now be viable.

2.1 Uncertainty Model

Propagation of Uncertainties

Input distributions may be normal, uniform, triangular, skewed, or any shape that reflects the nature of the measurement being assessed (see appendix 1 for examples). Using conventional analytical techniques [2], [3], the various distributions are handled in the same manner, consequently the resultant “Root Sum Square” (RSS) solution will give a “Normal” distribution regardless of the input type. The output distribution can also be in error depending on the input shapes, skewed from the actual true mean with no indication of or ability to calculate the offset value. Combination of distributions that are not symmetrical, or are poorly defined, to find system uncertainty is difficult to achieve using analytical mathematics and this problem is not confined to measurement uncertainty [4].

By utilising the MCS technique to combine distribution curves, the type of input will be reflected in the resultant output distribution, the correct propagation of distribution is carried forward (both in terms of returning actual means and uncertainty distributions). The example in figure 1 shows the combination of normal and triangular distributions, giving values for both conventional and MCS resultants.

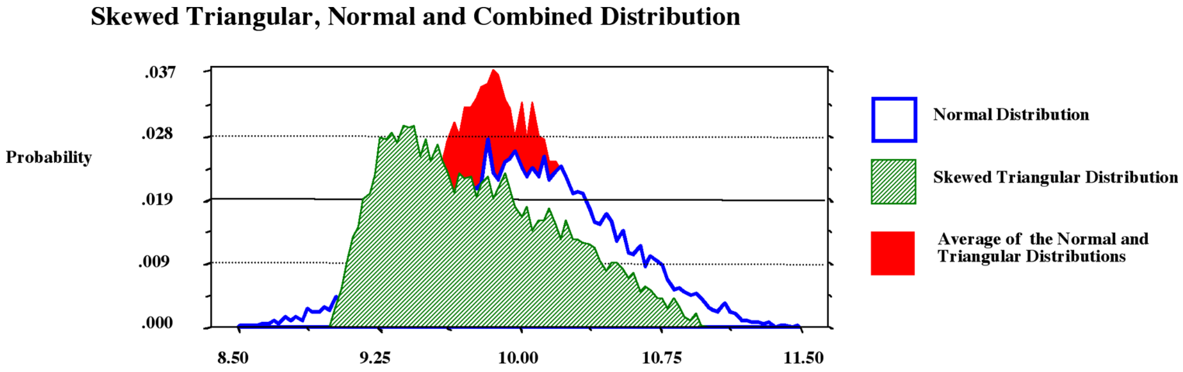


Figure 1

- A “Normal” distribution is generated with a mean of 10 with 95% confidence limits of +/-10%
- A “Skewed “Triangular” distribution is generated with a mean of 10 skewed to 9.3 with limits of +/-10% giving a mean of 9.77
- These distributions are averaged giving a “Gamma” distribution with a mean of 9.89. This is compared with the average of 10 if the means are found without knowledge of the distribution thus demonstrating how a systematic bias error may arise.

Comparison of Distribution Means	**Conventional**	**Monte Carlo**	**Discrepancy**
Triangular Distribution	10.00	9.77	0.23
Normal Distribution	10.00	10.00	0.00
Mean of the Average (Gamma Distribution) of Normal and Triangular Means	10.00	9.89	0.11

Building a System Model - Stage 1

The model is made up from various macro modules. These are joined together to form an interactive system, which is easy to manipulate by the user, whilst not compromising integrity. Taking each step at a time, we start the building of the model by looking at an individual stream on a measurement system. The user interface package is in pictorial format, allowing simple manipulation or data entry and even more importantly easy access to the results. The model is made up from a mixture of visual basic macros, excel sheets and incorporates MCS modules. The beauty of this build up approach is the fact it doesn’t matter what type of system is being analysed, orifice, ultrasonic, turbine etc. or even a mixture of all types can be accommodated.

The system inputs can be any of or a combination of the following; constant values, variables dependant on process conditions or results of calculations. The model is built to be generic for any particular type of device, the variants of input types e.g. density measured or calculated, can be selected by software switches. The model has the ability to handle snap shots of live values or user entered values.

Modelling an orifice system (see Fig 2) Visual basic modules handle the conventional processing of AGA8 line density and ISO5167 (DP uncertainty determination) inputs and results. Pressure and Temperature sensitivities are handled via an Excel spread sheet and outputs from these are fed into various MCS modules. In turn the results are fed through to final computation via more visual basic modules (ISO5167, ISO6976 and AGA8) giving values for Mass, Volume and energy (both quantity and uncertainty).

The distribution of the orifice meter stream mass, volume and energy flow rate found from the model in figure 2 yields a mean and uncertainty that agrees well with conventional methods when all uncertainty sources are considered. However by looking at the distribution and by comparing the mean with the true calculated value a small bias is observed. This is due to the non-linearity resulting from the square root of the density and differential pressure within the ISO5167 calculation. The bias, which is insignificant for a single stream, compounds as streams are combined leading to a larger system bias, overlooked by conventional uncertainty methods.

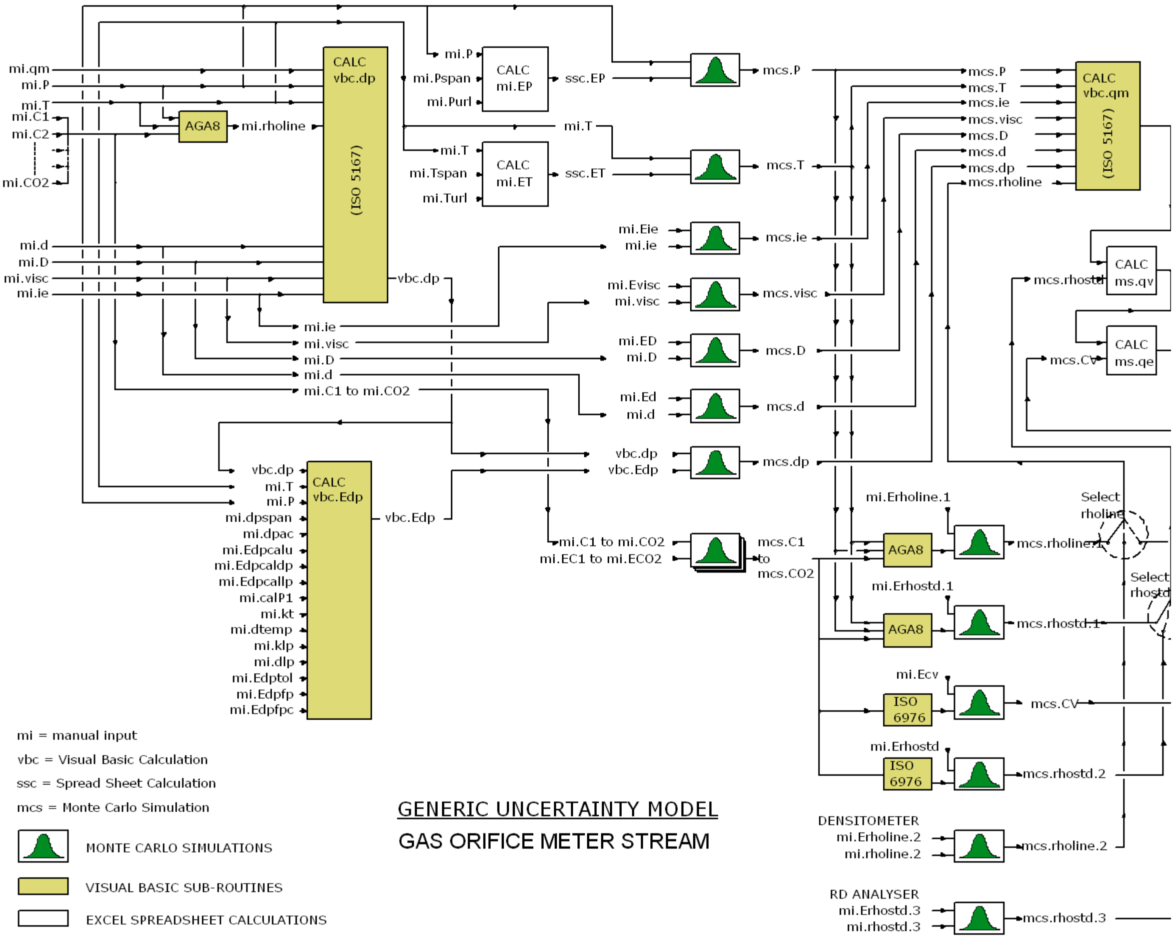


Figure 2

Building a System Model - Stage 2

Taking the single stream into the measurement station scenario, by the addition of extra streams (duplicate macro of first stream) a measurement station can be developed (see Fig 3).

Note: care must be taken with the common equipment, effects should not be calculated twice, the application should be selectable via software switches. The program should also give warning as to possible duplication of effects.

Also the model will negate the requirement for duplication of input variables. Again the system will be presented in pictorial format, showing the necessary intermediate values as well as the final summated outputs.

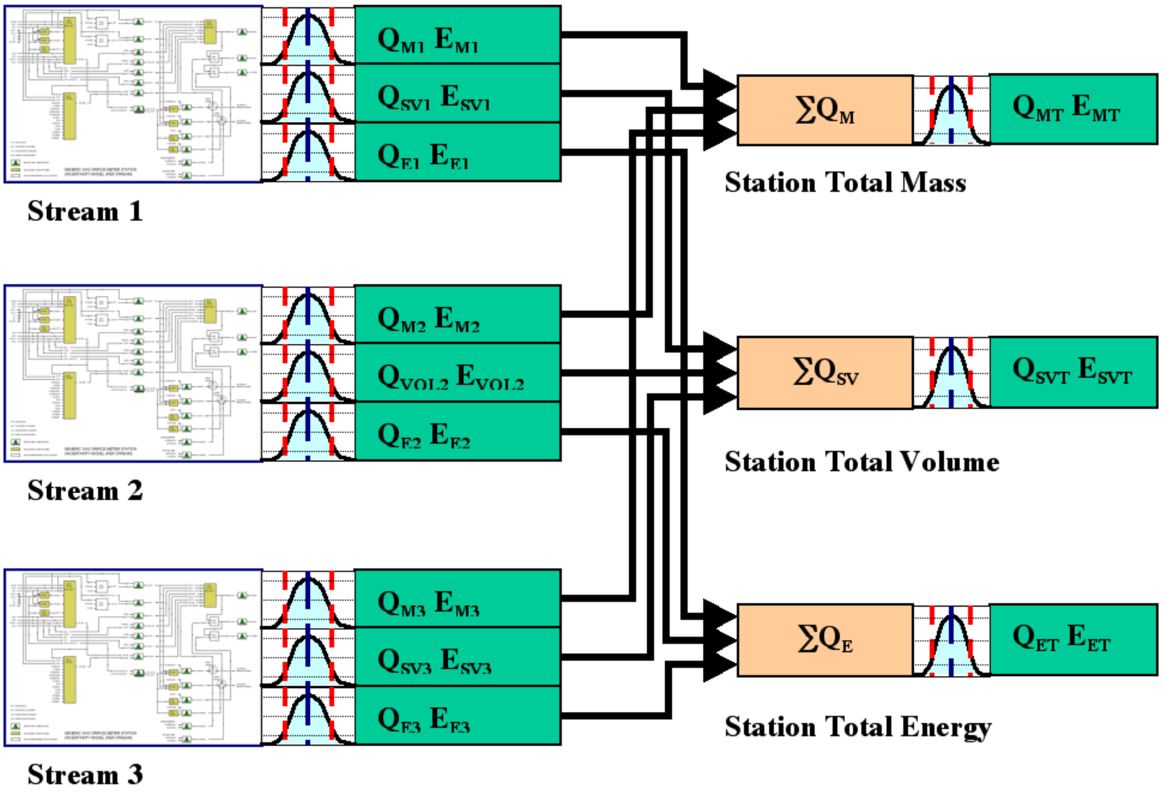
This gives the user his exposure, not only as a percentage of uncertainty, but also in actual value of output. The model can be used in cases of equipment failure to quickly identify the impact, and be used as a calculation basis for any mis-measurements required. The main exposure is to ensure that the agreement clauses for system uncertainty are being met, and if required to form the basis of a dispensation to allow continued operation based on exposure during equipment failures.

The simulated stream measurements are applied randomly to the model to give a set of flow rates with normal distribution. The total flow rate is found from the mean of the distribution and the uncertainty with a 95% confidence level found from twice the standard deviation. Between 20,000 and 100,000 simulation runs may be required to give a good definition to the resultant distribution, a rule of thumb is that as the number of input variables increases, so does the required number of runs – ratio of 1: 1000. Whilst this sounds onerous it will take less than a few minutes to complete, using modern powerful desk top computers and software packages.

The example in figure 3 shows three identical orifice meter streams. The discharge coefficient uncertainty and expansion factor uncertainty, which are common to all streams at the same flow rate, are combined with the individual stream uncertainties. With conventional methods this is found from the RSS of the uncertainties whereas with MCS methods the uncertainty distributions are summed and the uncertainty is found from the mean and 95% confidence limits of the resulting distribution.

When the uncertainty results are compared the MCS uncertainty is found to be less than the RSS uncertainty, which is due to the combination of the slight bias in each stream distribution. When the true result is compared to the MCS distribution mean the bias observed is greater than the bias observed for a single stream but is nevertheless small. The RSS method of combining uncertainties overestimates the system uncertainty and does not identify the system bias and strictly speaking is invalid for propagating uncertainties with an inherent bias.

Figure 3



Station Model

- Mass Uncertainty
- Volume Uncertainty
- Energy Uncertainty

Building a System Model - Stage 3

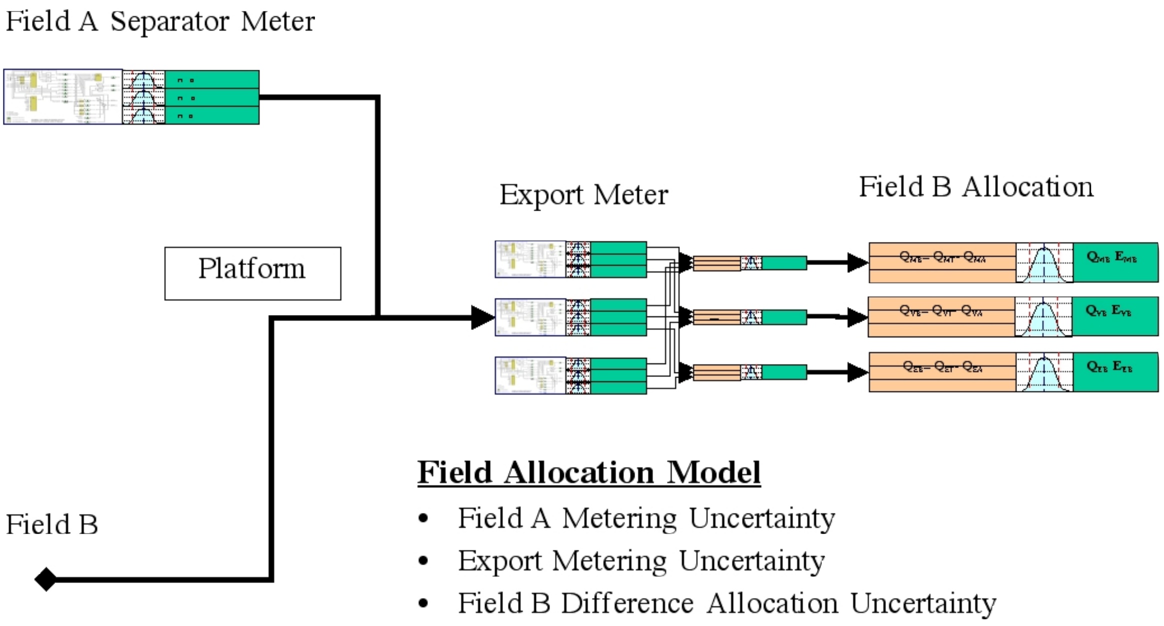
The previous stage developed a measurement station. If this station were part of a bigger picture, a plant or multi-user pipeline, it would have an impact on the resultant output values. The export station of the system will determine the size of the pot (or pie) while the input systems will determine the share of the pot (or pie). If we refer to each measurement station as a nodal point within an overall system the model can then take its third step. A system model built up of all the nodal points, again in an overall pictorial image allowing the system manager the values at each point and the associated uncertainties. This means a decision affecting the system can be made based on sound information, allowing for optimal usage of system resources and giving knowledge of key areas of impact.

As the system grows the simulation run time will increase, however this can be negated by increasing processing capacity.

The building blocks can be utilised for the development of any type of system arrangement. An allocation system, looking at the terminal and field meters, can give by difference determinations of unmeasured inputs in terms of value and uncertainty (see Fig 4). Pipeline models, for use with multiple partner systems, can give each individual quantity, exposure and tax liability (see Fig 5). Being user configurable any combination of stations is possible giving any output requirement.

Allocation / Reservoir Management

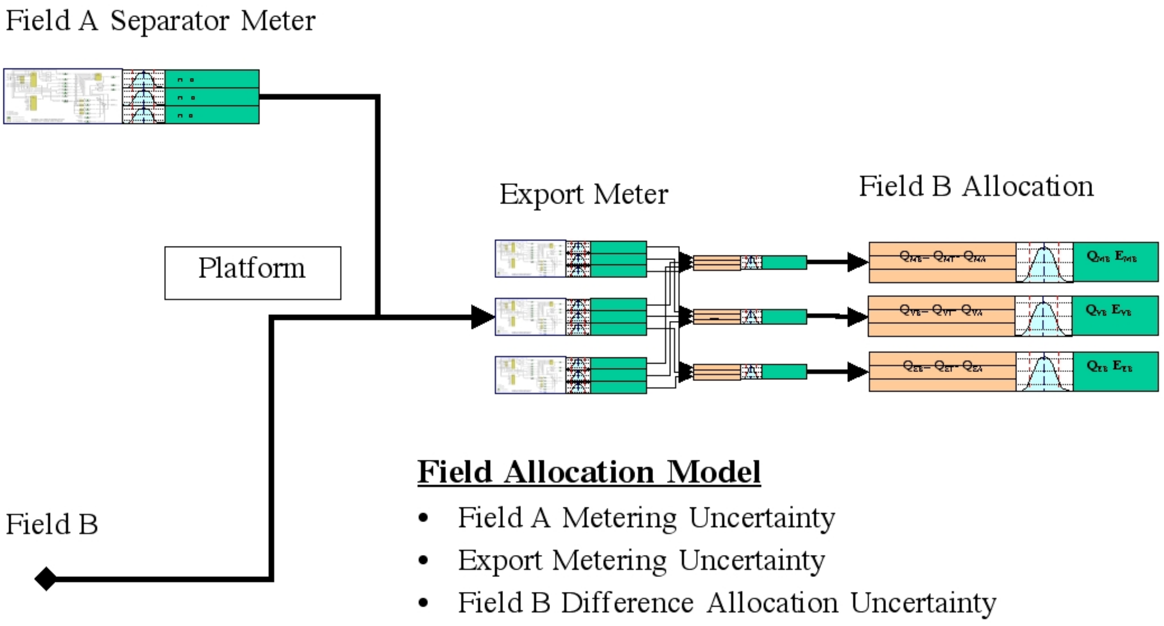
Once the model has been tested, the input values can be tied to live data sources. Simulation must be run in batches, giving the user the required data for production totals and consequent Gas / Oil ratios, daily or as frequently as hourly. The possibility exists to build up a case history, utilising well tests, compositional analysis, production parameters and choke positions to generate figures whilst the measurement equipment is unavailable on any particular inlet separator.



Field Allocation Model

- Field A Metering Uncertainty
- Export Metering Uncertainty
- Field B Difference Allocation Uncertainty

Figure 4



Field Allocation Model

- Field A Metering Uncertainty
- Export Metering Uncertainty
- Field B Difference Allocation Uncertainty

Figure 5

Benefits for Project Work

The model approach gives two main benefits for any project group; firstly it can provide the necessary station or system uncertainties at hand over to operations and secondly it allows the project team to quickly quantify the various options available to them in terms of meeting the agreement or system operator stipulated limits.

By utilisation of a derived system model of a facility, the inputs to the various separators can easily be manipulated. The life cycle of wells can mean, where once a separator was fully utilised it may now have the potential for another stream due to the decline in the existing well. This gives the potential for the processing of new fields across existing facilities, however it can be difficult getting funds if the potential financial expenditure is not kept to the minimum. In manipulating the various options, gaining answers on quantities and uncertainties, the project team can quickly identify the preferred options and equipment needed. Also the model will give necessary data for presentation of the viable case based on best utilisation of existing facilities. This gives the potential for previously shelved projects to be revisited, and by correct manipulation of equipment made viable.

3.0 CONCLUSIONS

- Forming an alliance between operators and service companies ensures a product is developed faster with the necessary interface and output requirements needed to be utilised by industry.
- The standard static statement of uncertainty value produced as part of the project groups hand over package, has been superseded with a dynamic easily updated figure which can be used by the operations to optimise system management and identify areas with the greatest exposure for effective resource utilisation.
- System allocation and measurement spot checks can be run quickly providing the required information to enable fast determination of value for accounting purposes.
- Project groups can quickly identify the best utilisation of existing facilities when accommodating new field developments. Both in terms of flow and uncertainty for both the installation and also potentially the system to which it enters.

REFERENCES

[1] Basil, M. and Jamieson, A. W. (1998). Uncertainty of Complex Systems by Monte Carlo Simulation, North Sea Flow Measurement Workshop, Gleneagles, 26 – 29 October 1998

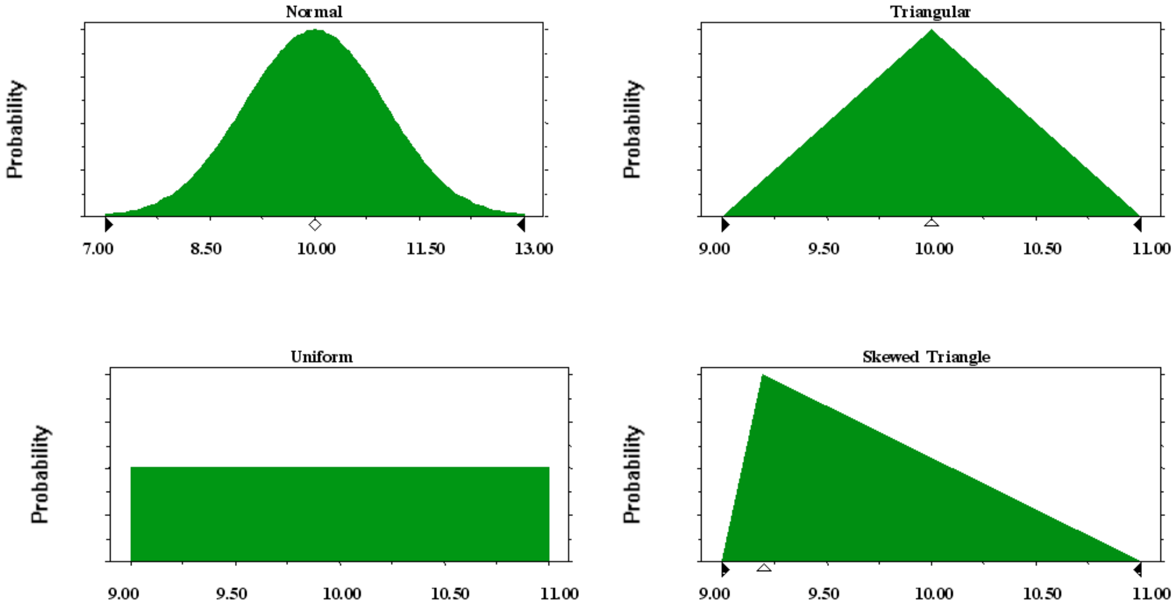
[2] British Standards Institution (BSI), Guide to the expression of uncertainty in measurement, PD6461: Part 3: 1995.

[3] International Organization for Standardization (ISO): Measurement of fluid flow – Evaluation of uncertainties, ISO5168TR: 1998.

[4] Mooney C. Z., Monte Carlo Simulation, Quantitative Applications in the Social Sciences Series, Sage Publications Inc, 1997.

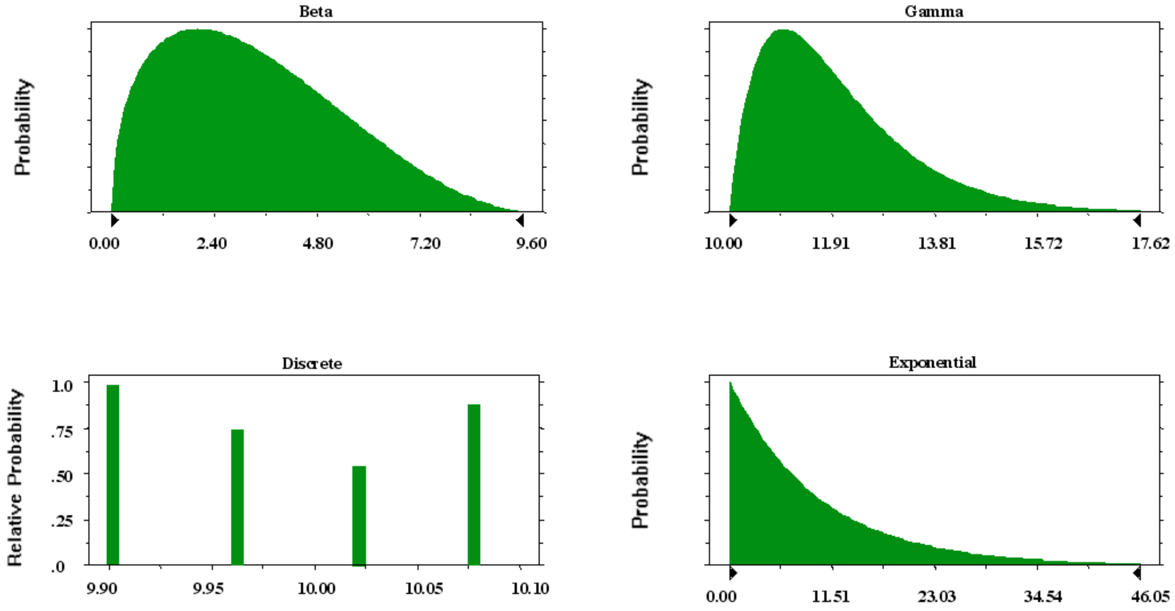
APPENDIX 1A

Typical Randomly Generated Input Distributions



APPENDIX 1B

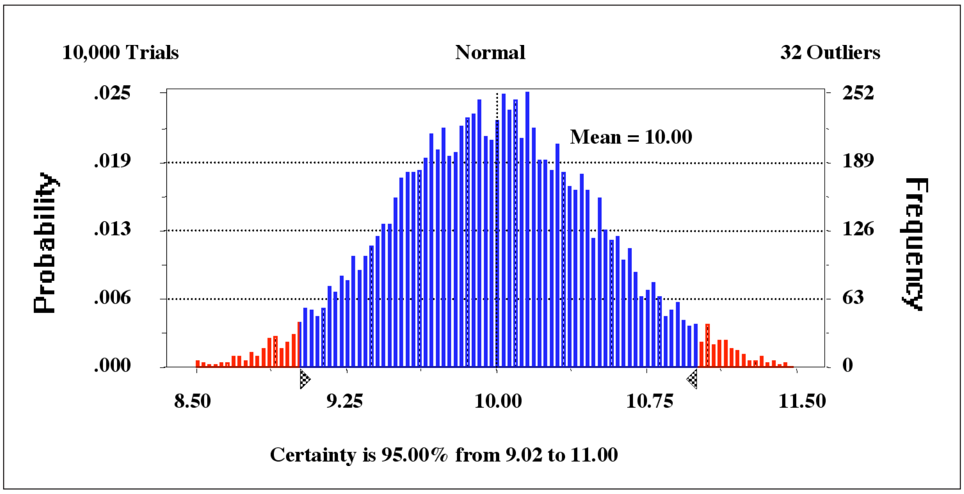
Asymmetric Randomly Generated Input Distributions



APPENDIX 2A

A Typical Normally Distributed Output

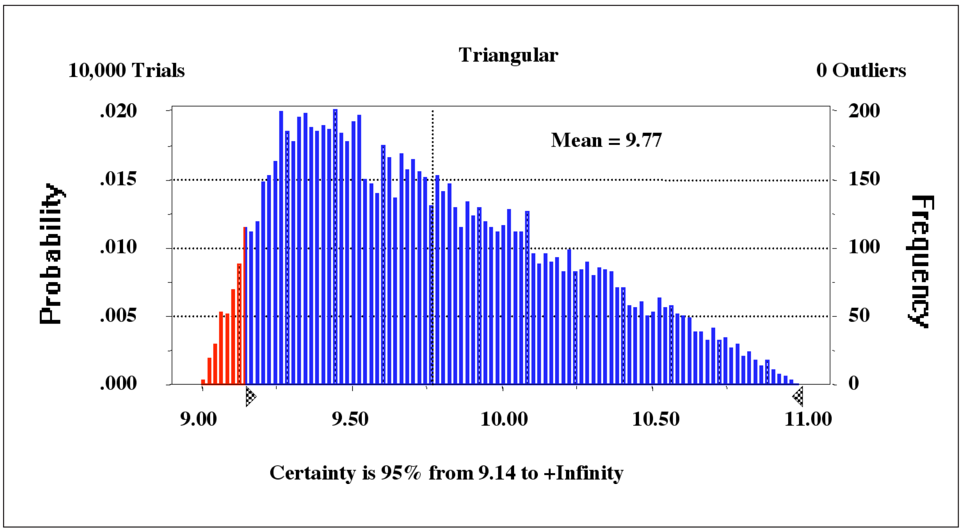
Outputs within the 95% confidence limits shown with arrows. The uncertainty is defined as the 95% confidence limits that are at 2 (1.96) standard deviations limits.
10,000 trials shown would be needed for a large model and for more presentable results.



APPENDIX 2B

Output of a Triangular Distribution

The result is offset from the correct mean of 10 by -0.23 with the 95% confidence limits only the left hand side.



APPENDIX 2C

Output of the Average of a Normal Distribution and a Triangular Distribution

Outliers show the results that are out with limits for the dataset

95% confidence limits (shown as certainty limits) to illustrate bias