

Hedging your bets? Impact of equity in multiple fields on owner's product allocation uncertainty

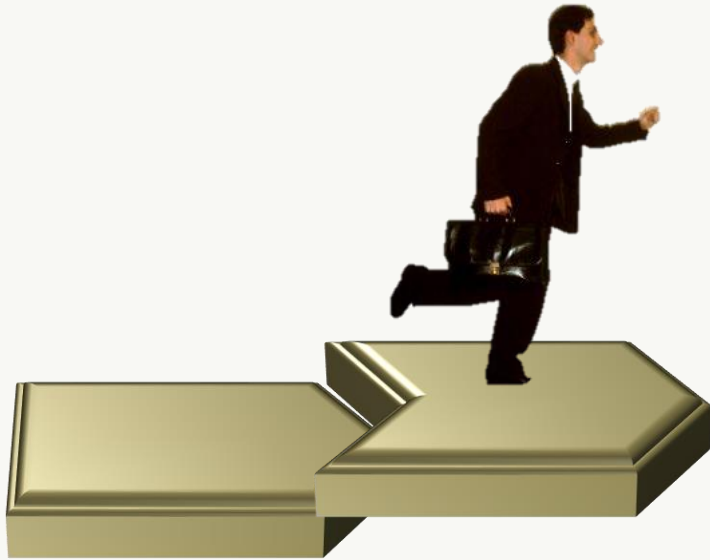
12th June 2025





1 platform
2 fields
OilCo
100% in
one field

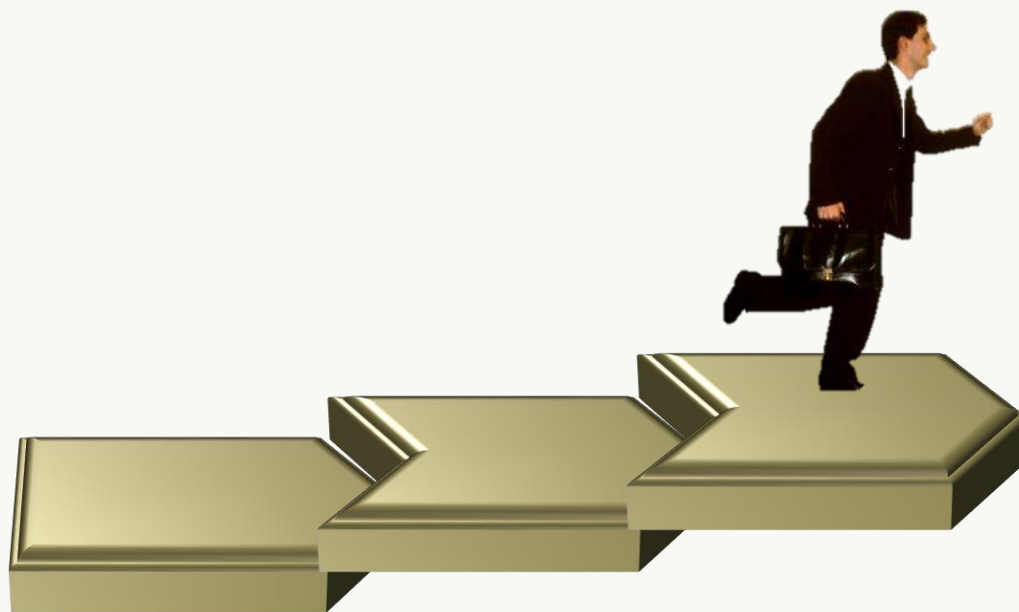




1 platform
2 fields
OilCo
100% in
one field

1 platform
2 fields
OilCo
50% in
each field



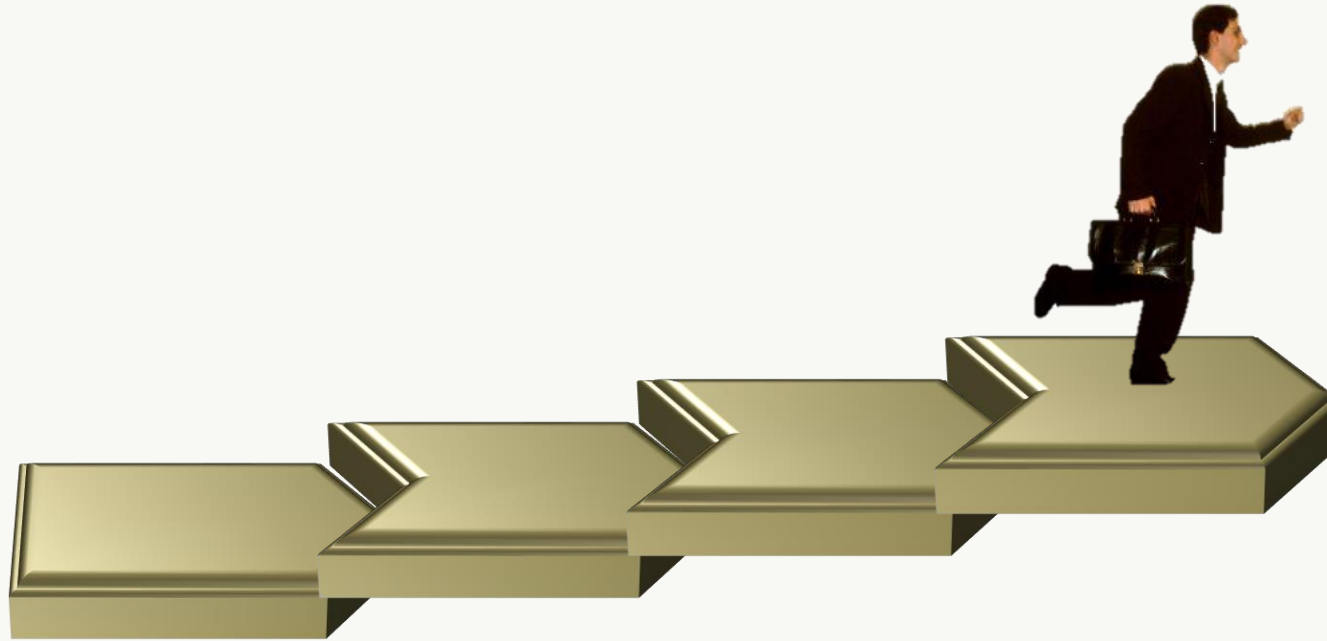


1 platform
2 fields
OilCo
100% in
one field

1 platform
2 fields
OilCo
50% in
each field

2 platforms
OilCo 50%
in each
platform





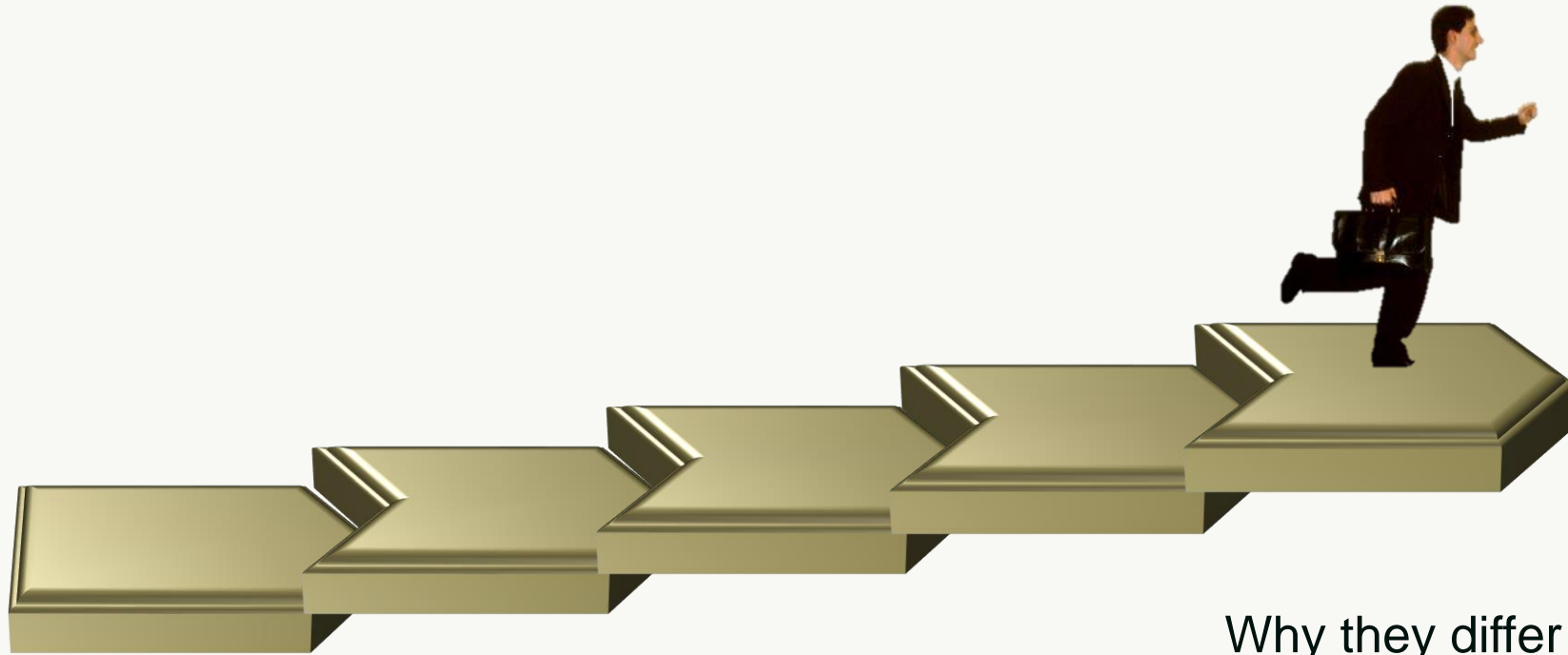
1 platform
2 fields
OilCo
100% in
one field

1 platform
2 fields
OilCo
50% in
each field

2 platforms
OilCo 50%
in each
platform

OilCo
Allocation
uncertainty





1 platform
2 fields
OilCo
100% in
one field

1 platform
2 fields
OilCo
50% in
each field

2 platforms
OilCo 50%
in each
platform

OilCo
Allocation
uncertainty

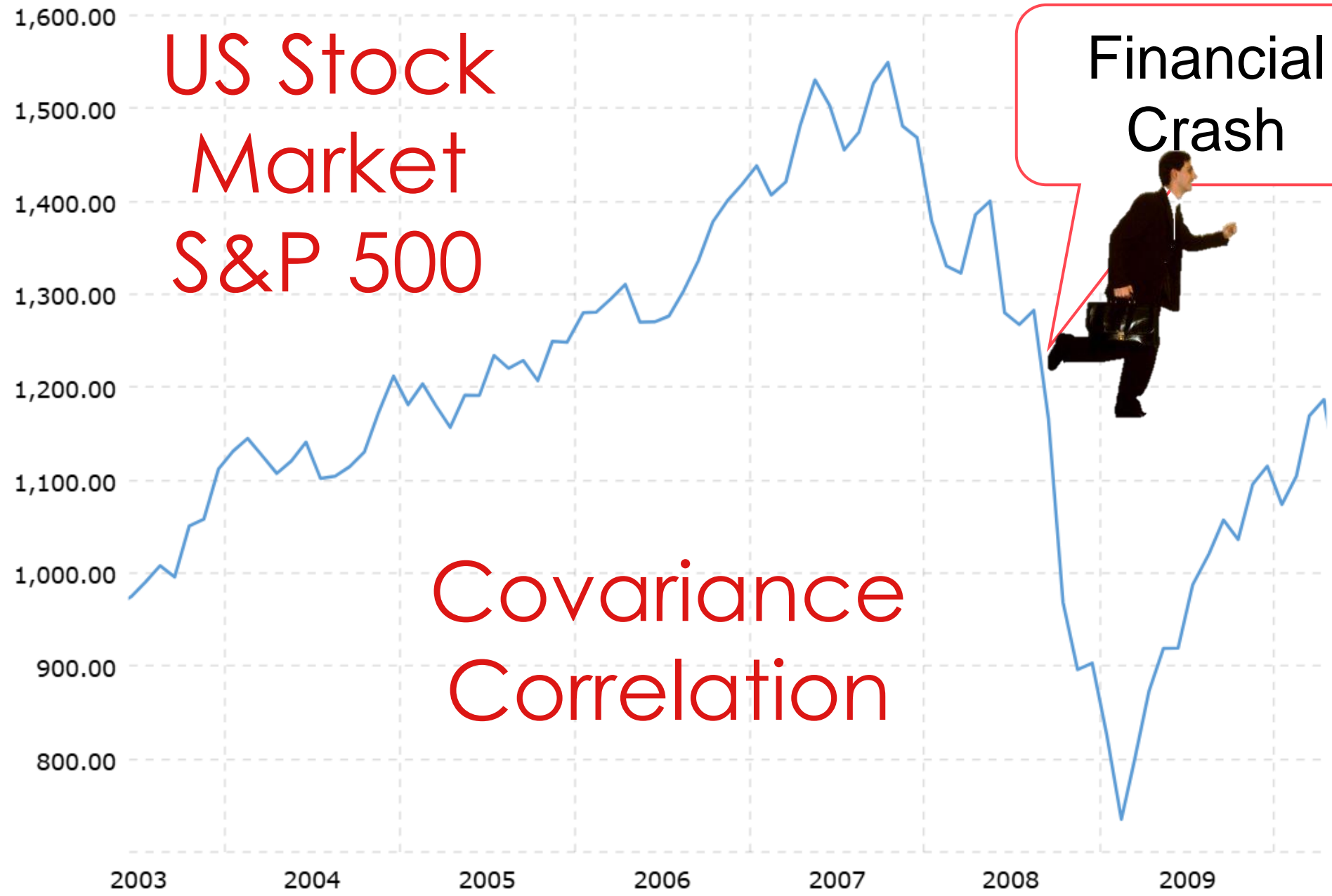
Why they differ



US Stock Market S&P 500

Financial Crash

Covariance Correlation



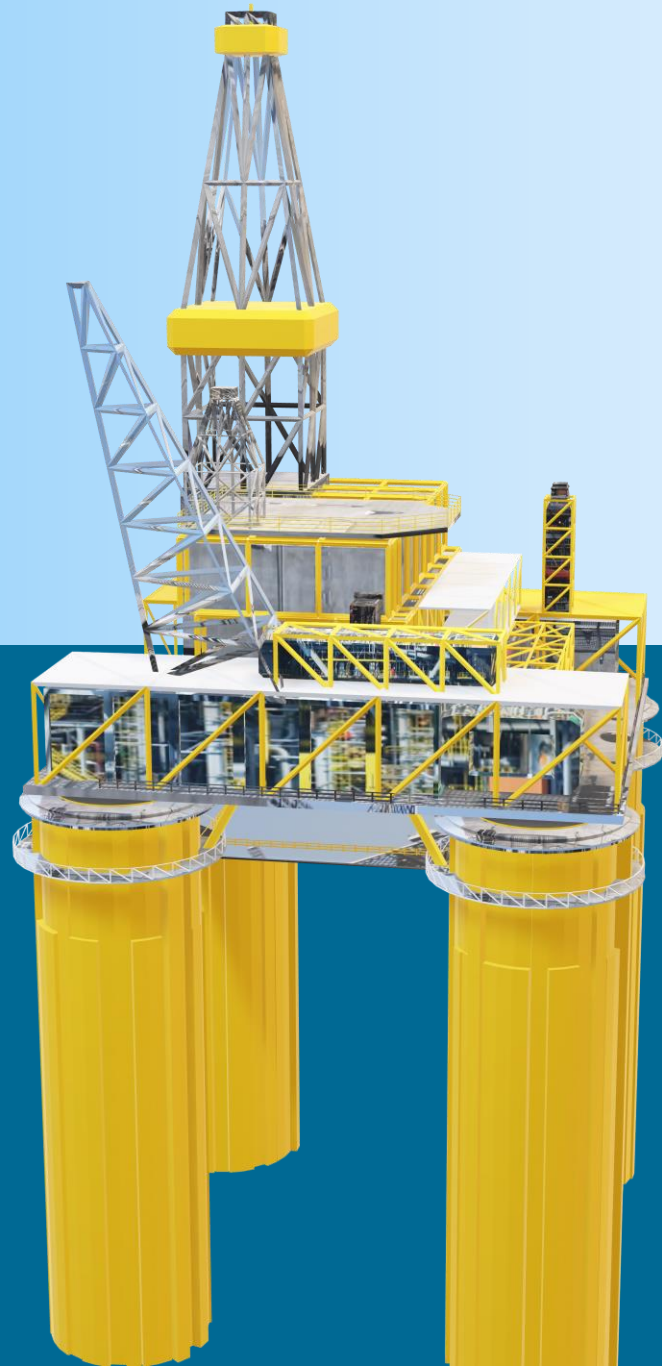


Platform Alpha Production

Field A measured 1,000 te $\pm 5\%$

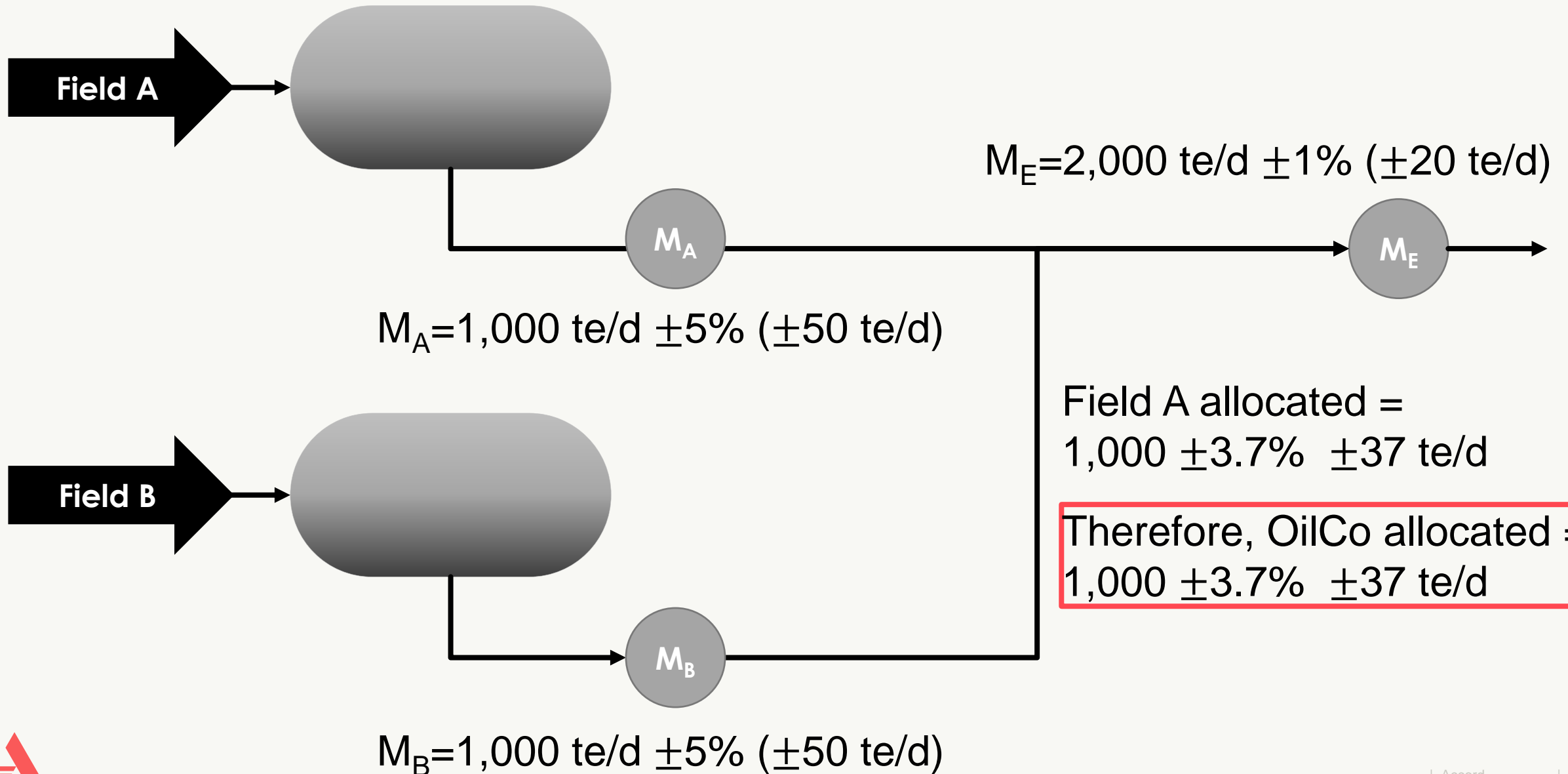
Field B measured 1,000 te $\pm 5\%$

Total measured 2,000 te $\pm 1\%$

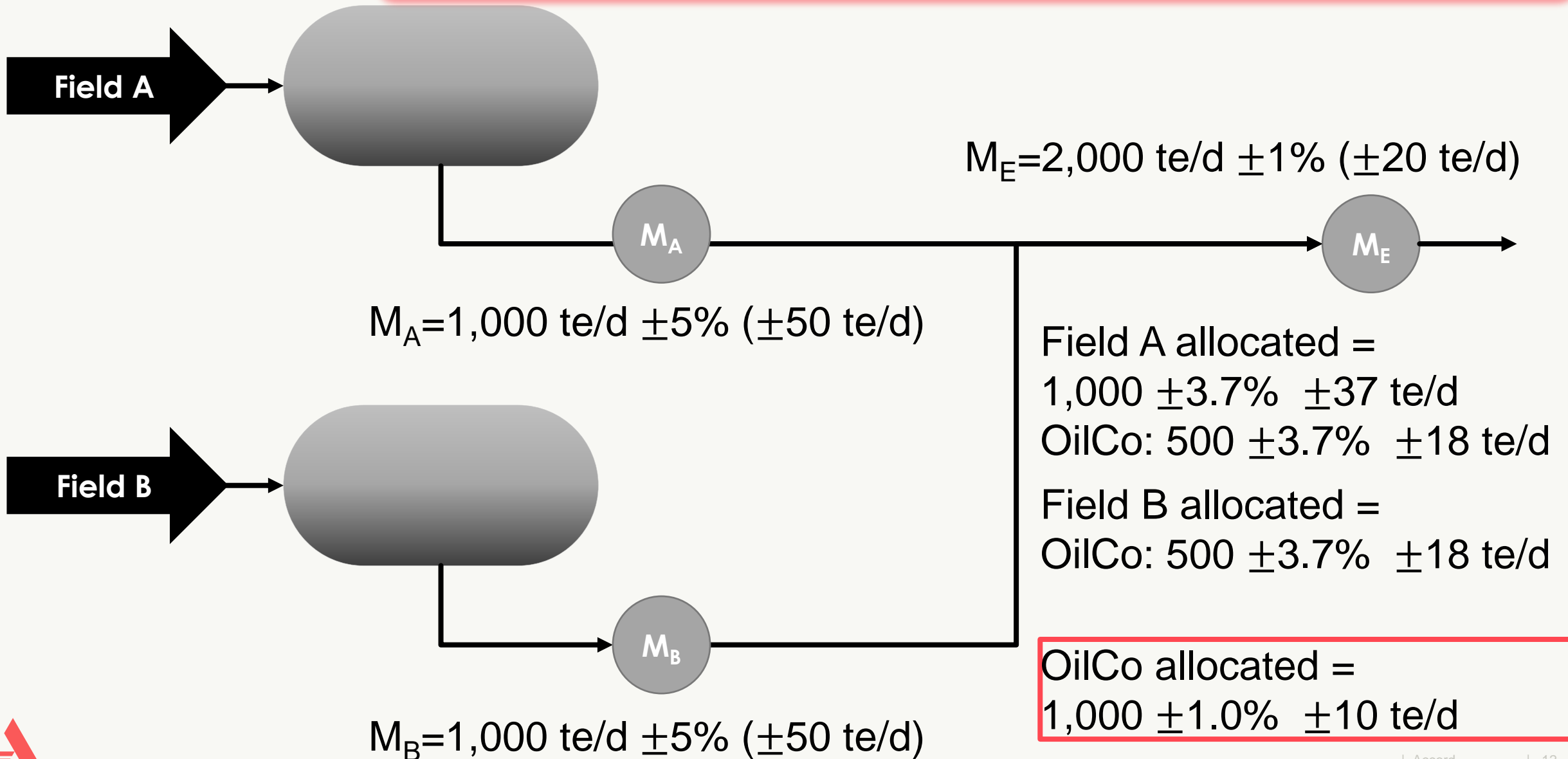




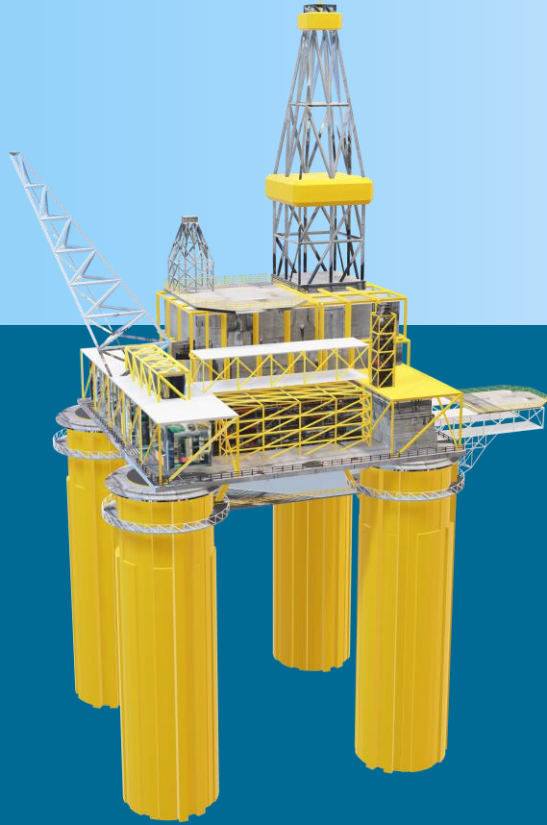
OilCo has 100% equity share of Field A



OilCo has 50% equity shares of Fields A & B



Platform Alpha



OilCo Allocation

Field A allocated 500 te $\pm 3.7\%$

Field B allocated 500 te $\pm 3.7\%$

Total 2,000 te $\pm 1\%$

Platform Bravo



Platform Alpha



OilCo Allocation

Platform Alpha allocated 500 te/d $\pm 3.7\%$ (± 18 te/d)

Platform Bravo allocated 500 te/d $\pm 3.7\%$ (± 18 te/d)

Total allocated 1,000 te/d $\pm 2.6\%$ (± 26 te/d)

Platform Alpha

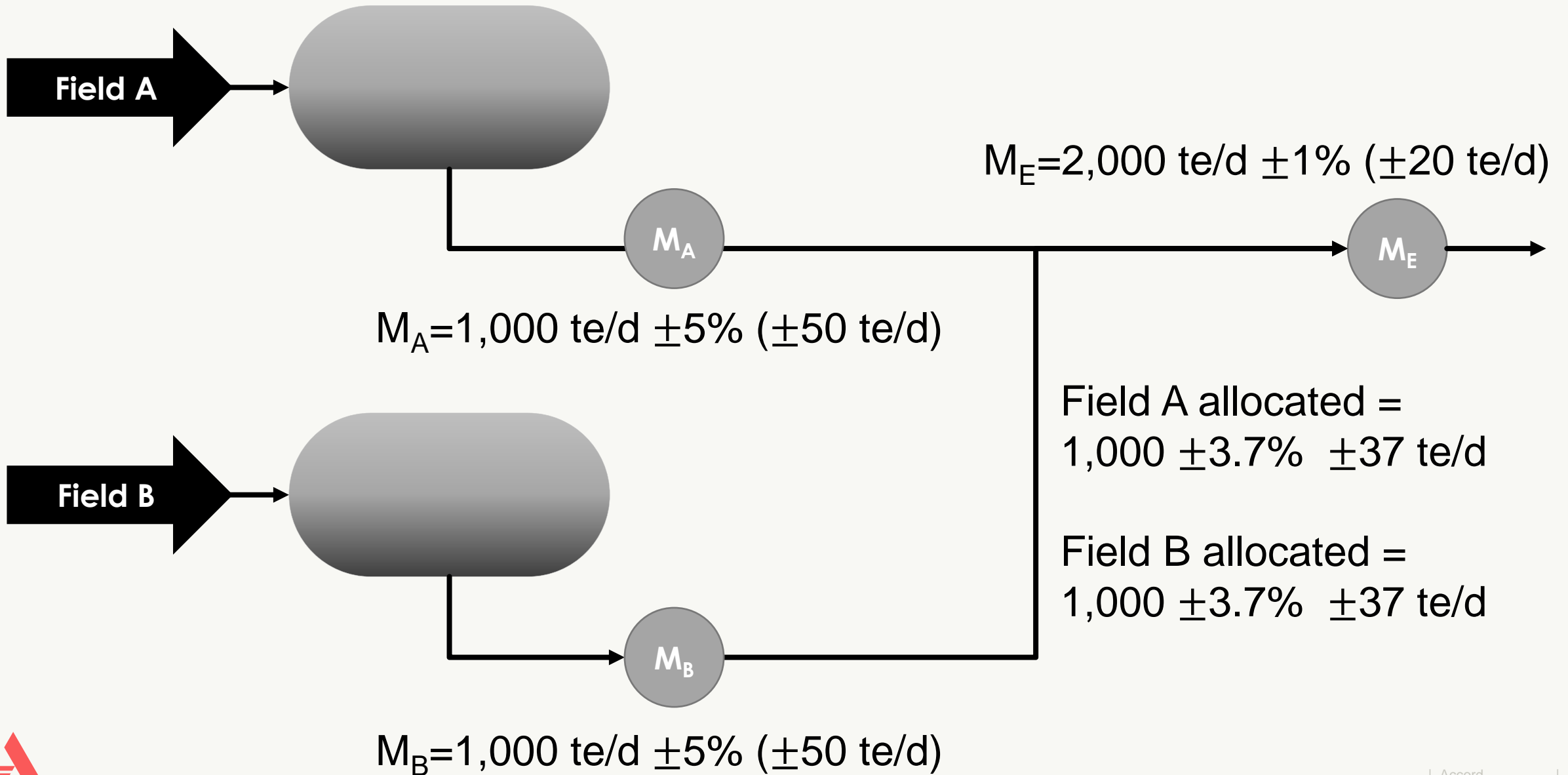


Platform Alpha Production

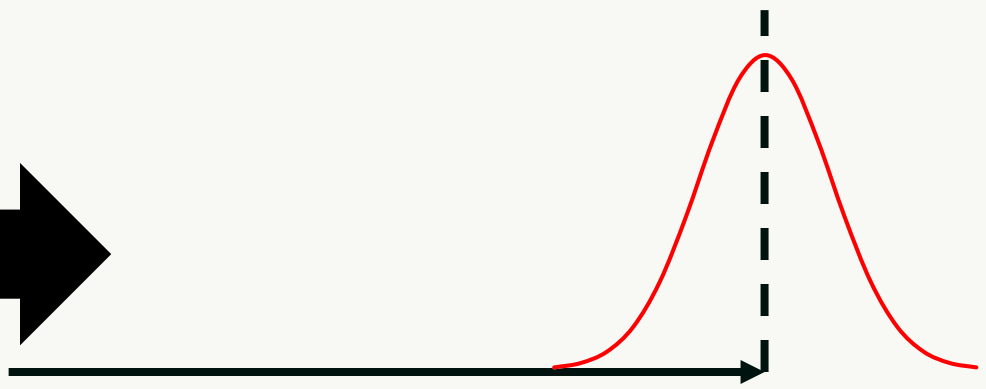
Field A measured 1,000 te $\pm 5\%$

Field B measured 1,000 te $\pm 5\%$

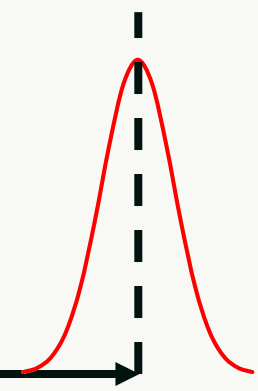
Total measured 2,000 te $\pm 1\%$



Field A

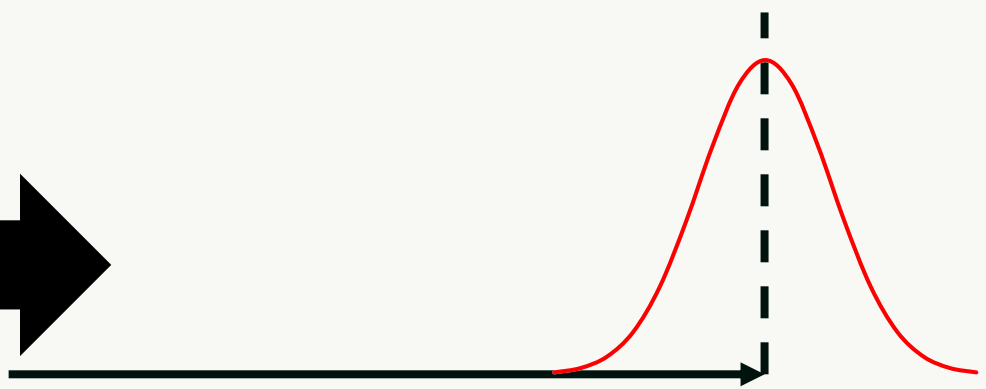


$$M_A = 1,000 \text{ te/d} \pm 5\% \pm 50 \text{ te/d}$$



$$M_E = 2,000 \text{ te/d} \pm 1\% \pm 20 \text{ te/d}$$

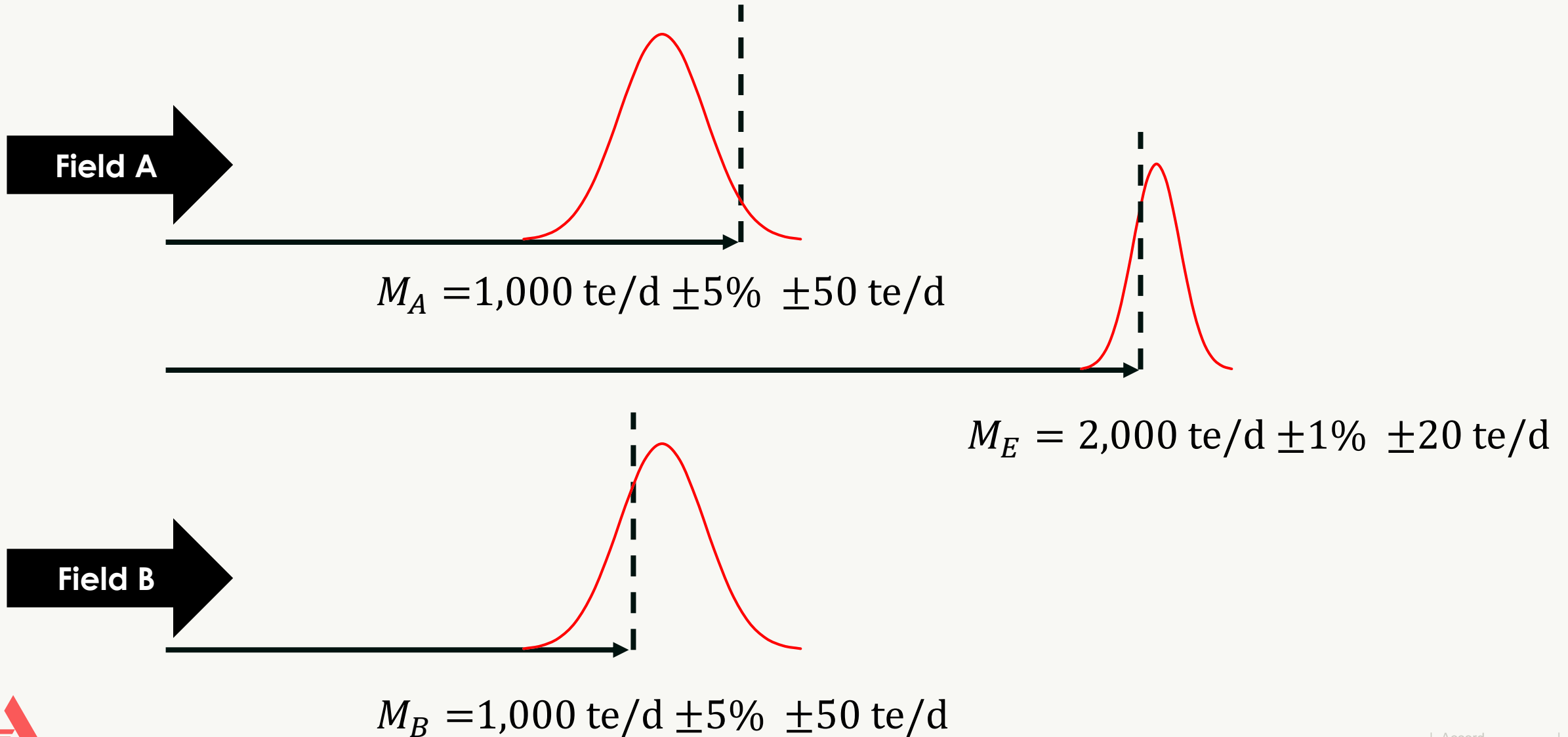
Field B



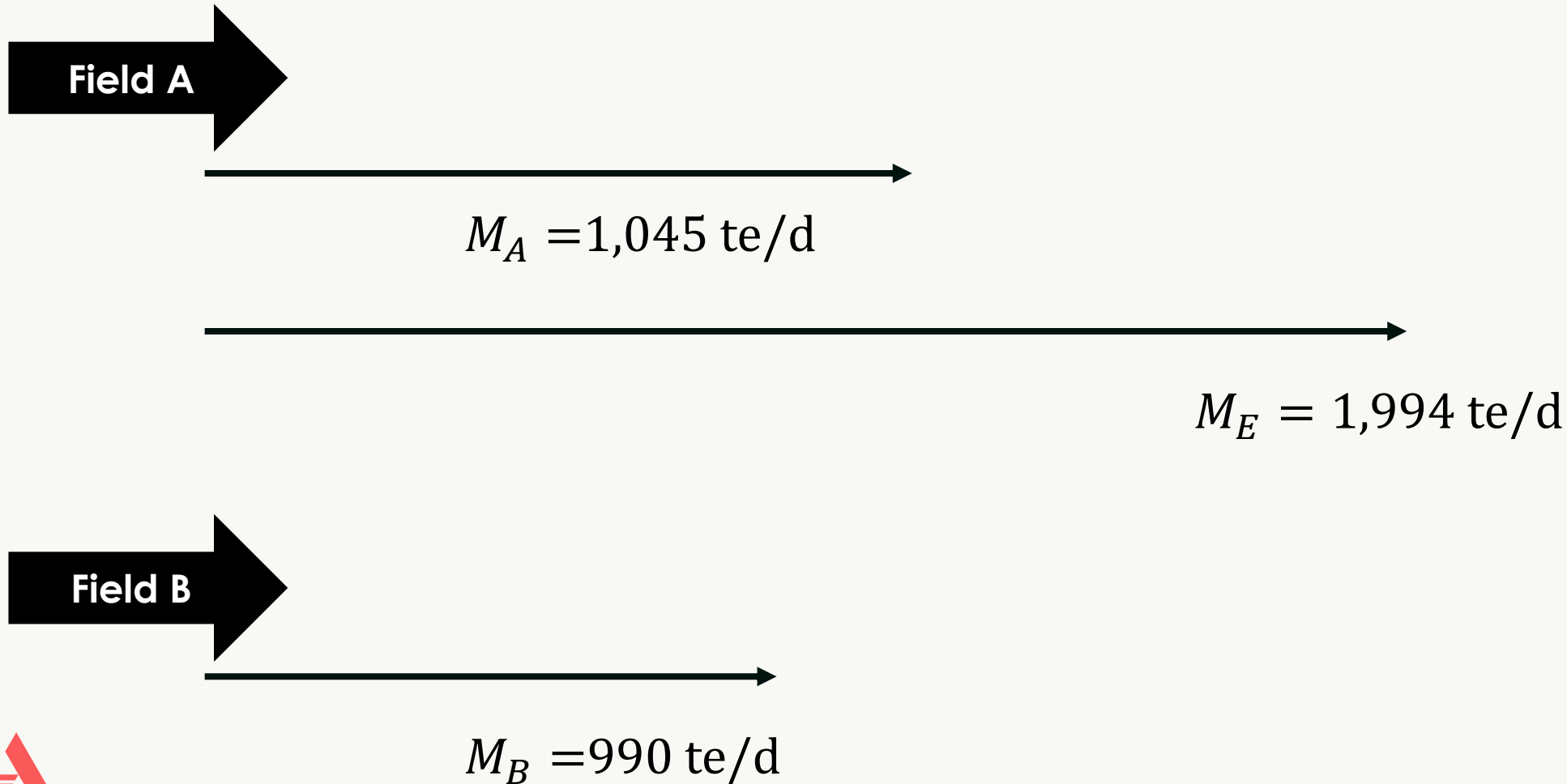
$$M_B = 1,000 \text{ te/d} \pm 5\% \pm 50 \text{ te/d}$$



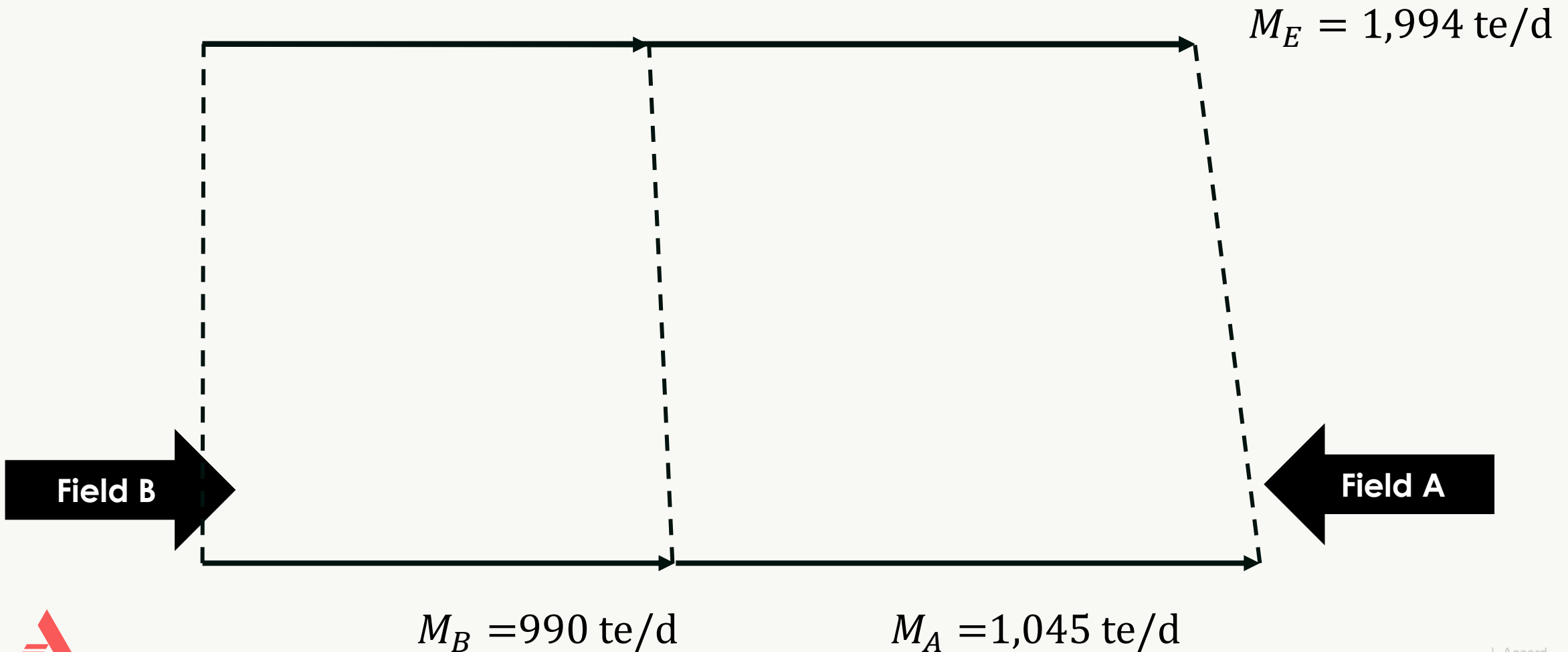
Steady production random uncertainty



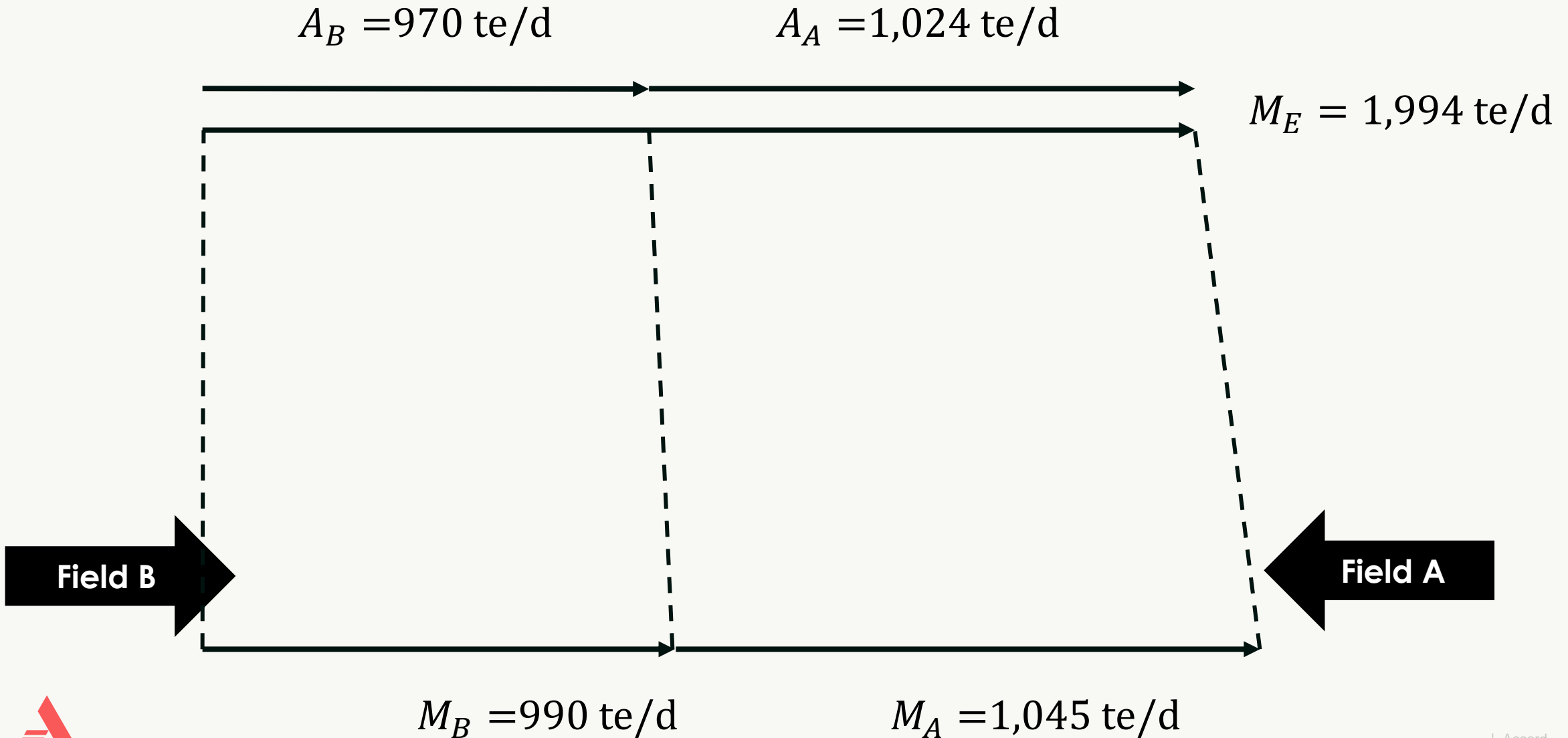
Steady production random uncertainty



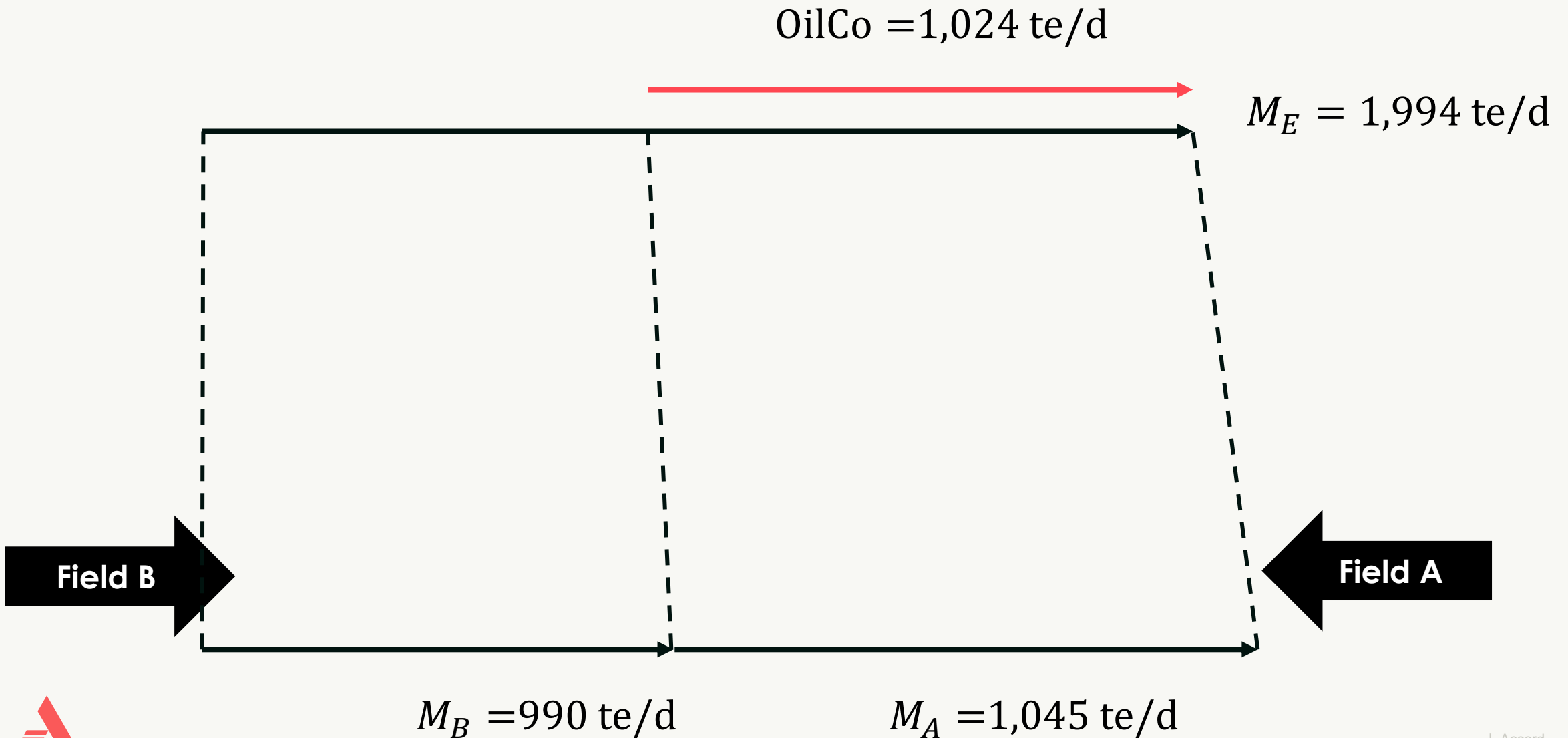
Steady production random uncertainty



Steady production random uncertainty

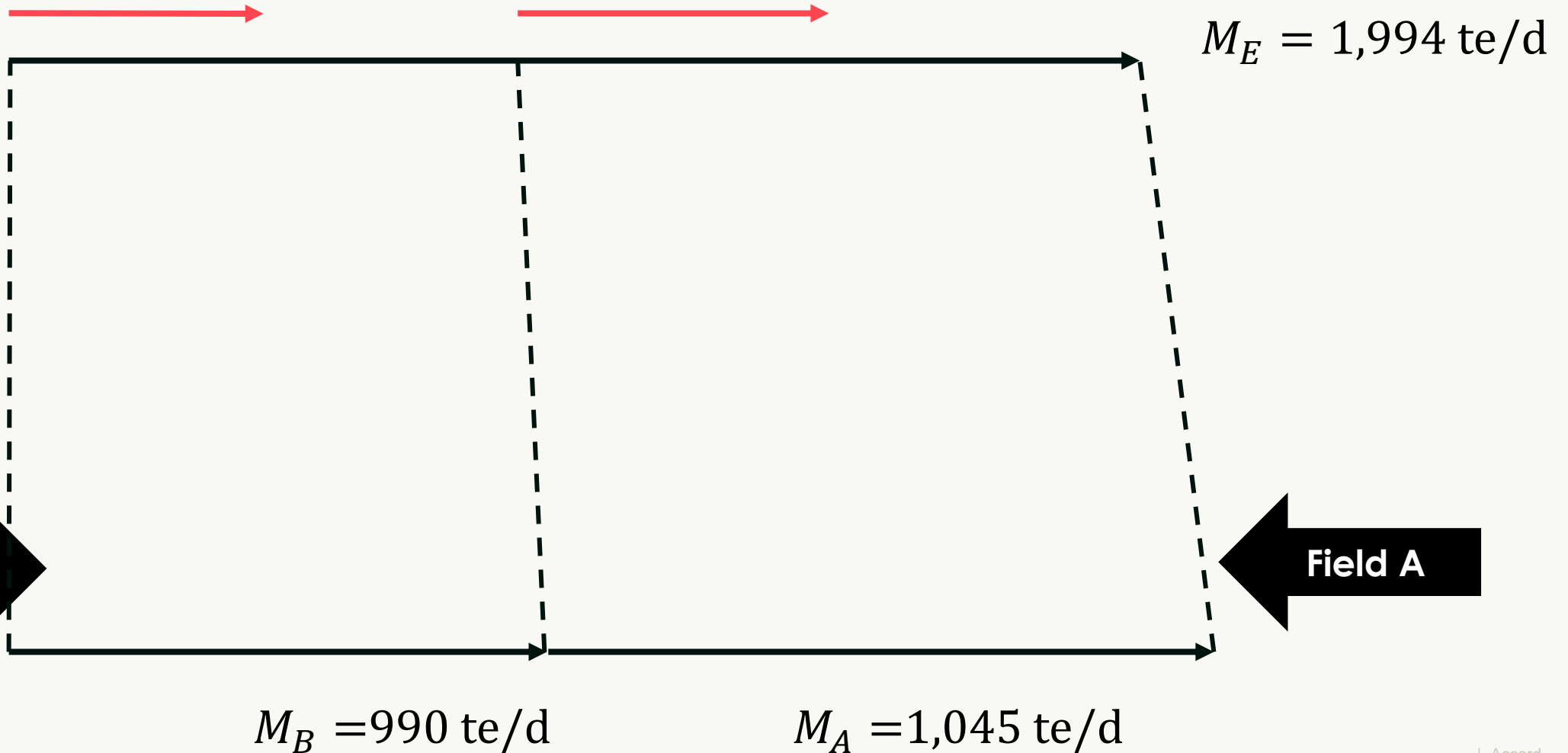


Oilco Allocation 100% Field A



Oilco Allocation 50% Fields A & B

$$\text{OilCo} = 485 + 512 \text{ te/d}$$

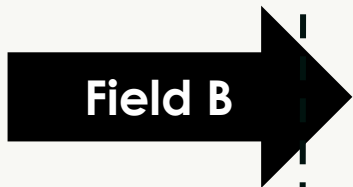


Oilco Allocation 50% Fields A & B

$$\text{OilCo} = 485 + 512 \text{ te/d} = 997 \text{ te/d}$$



$$M_E = 1,994 \text{ te/d}$$

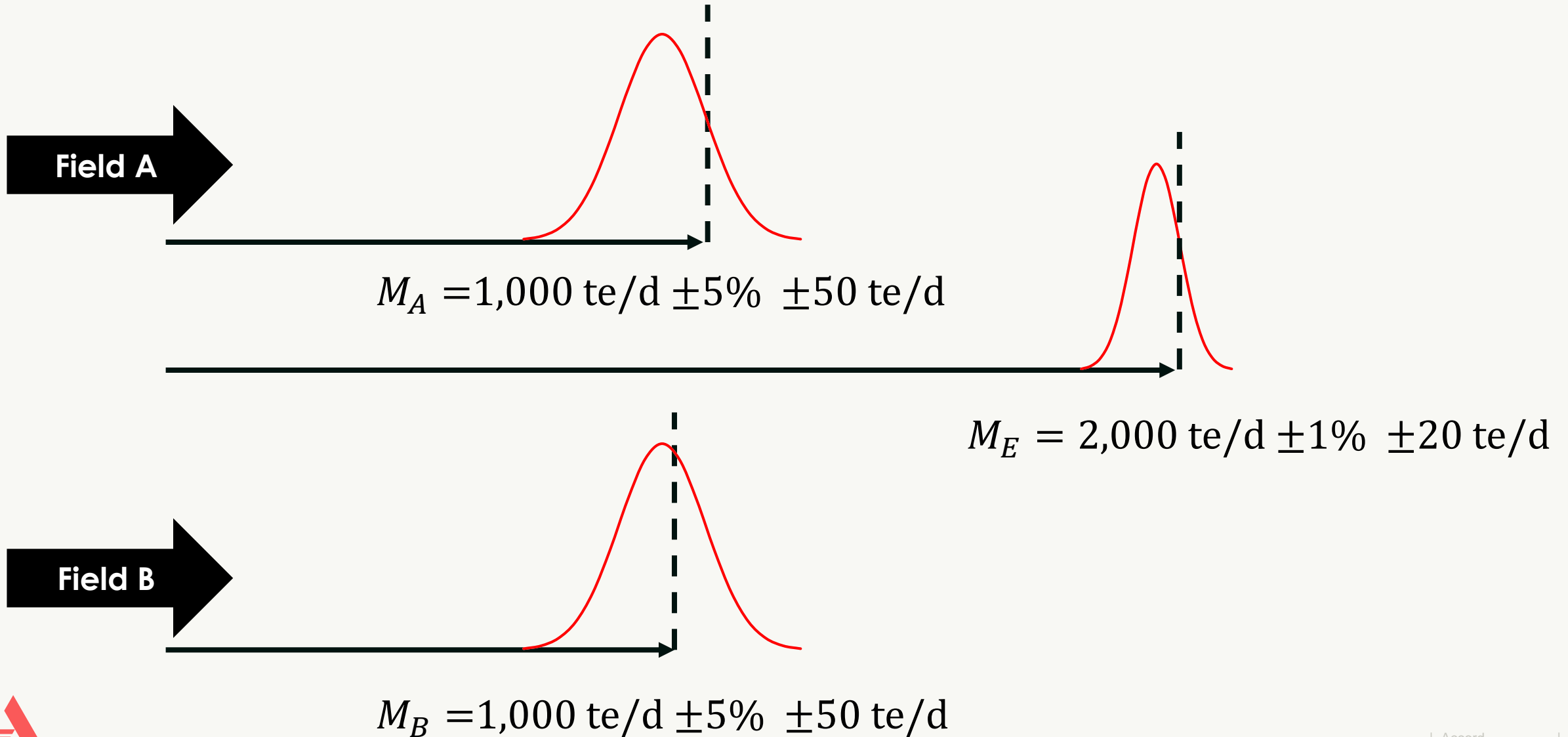


$$M_B = 990 \text{ te/d}$$

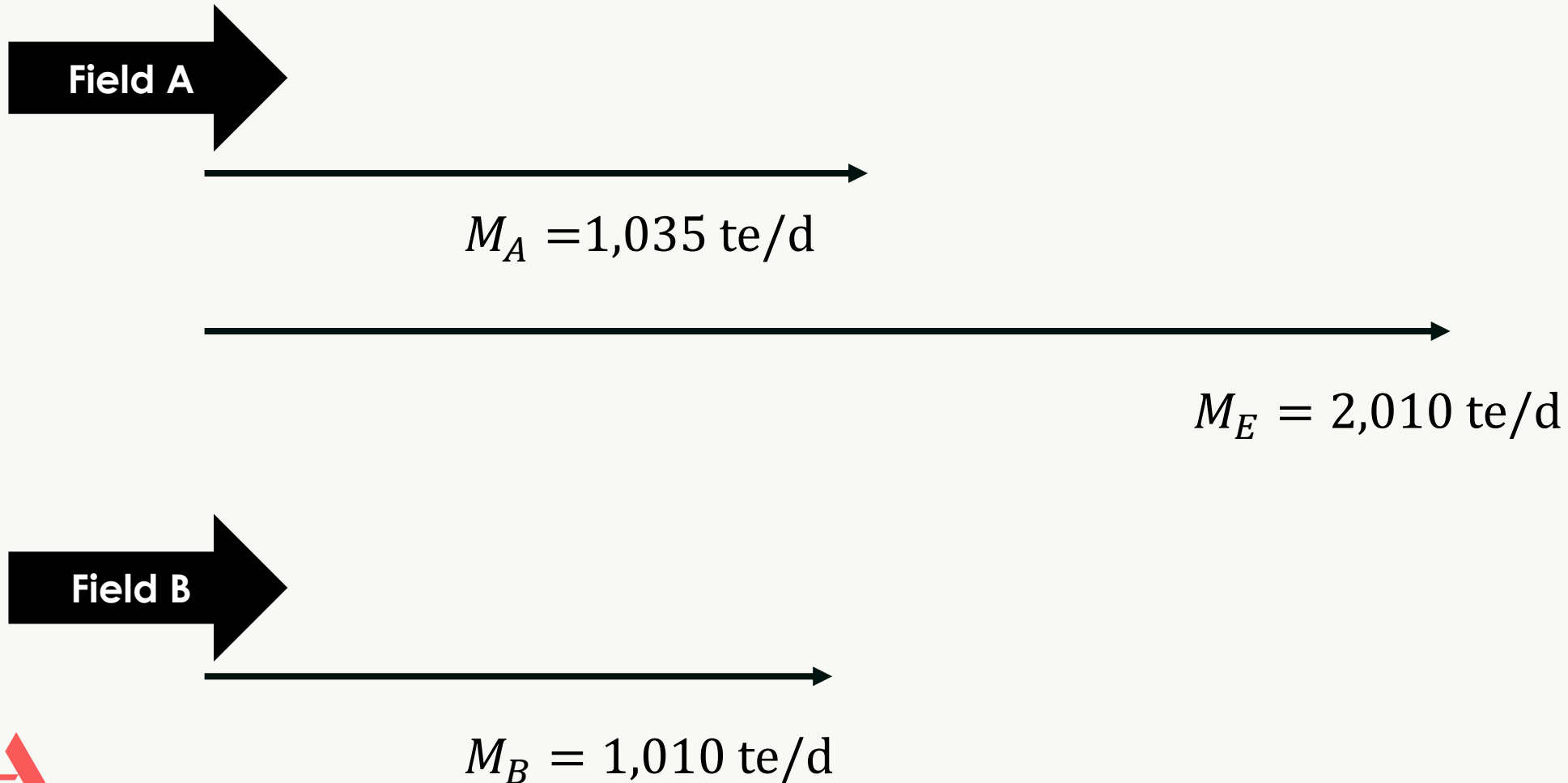
$$M_A = 1,045 \text{ te/d}$$



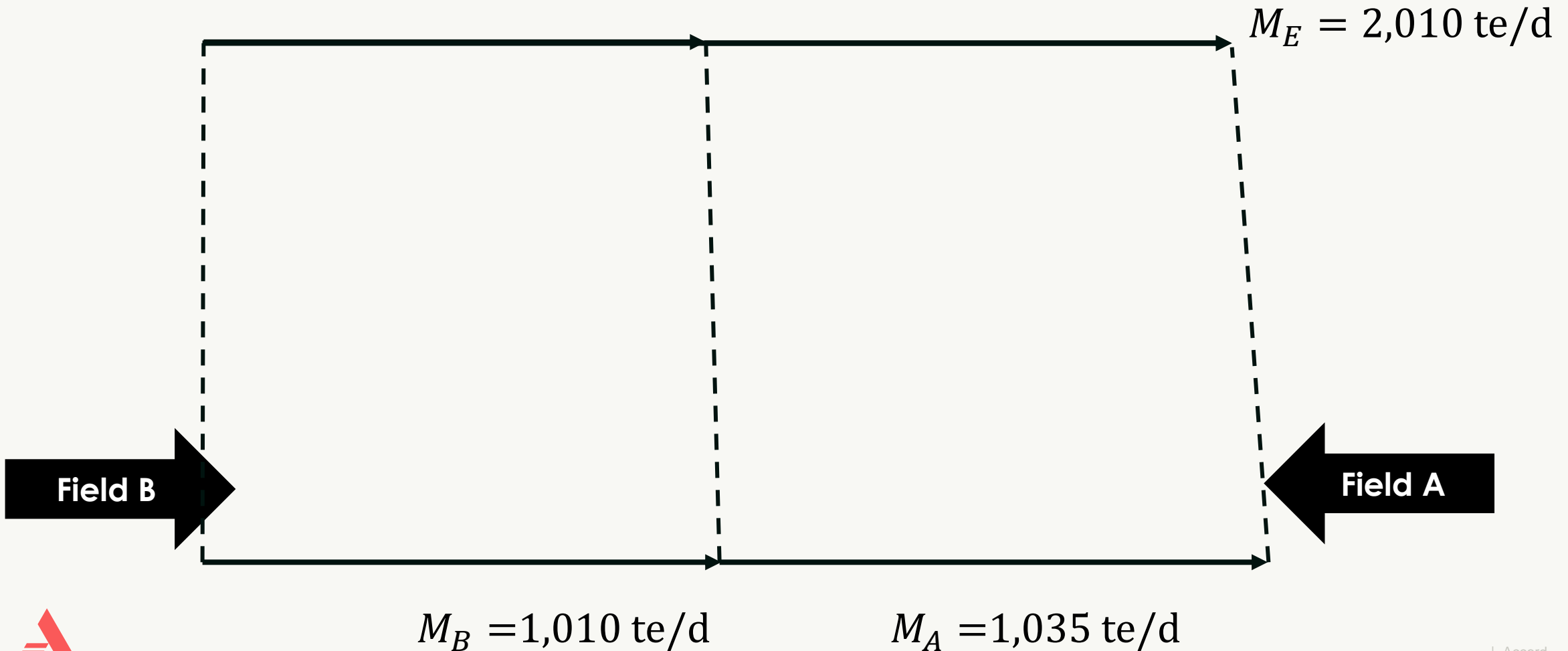
Steady production random uncertainty



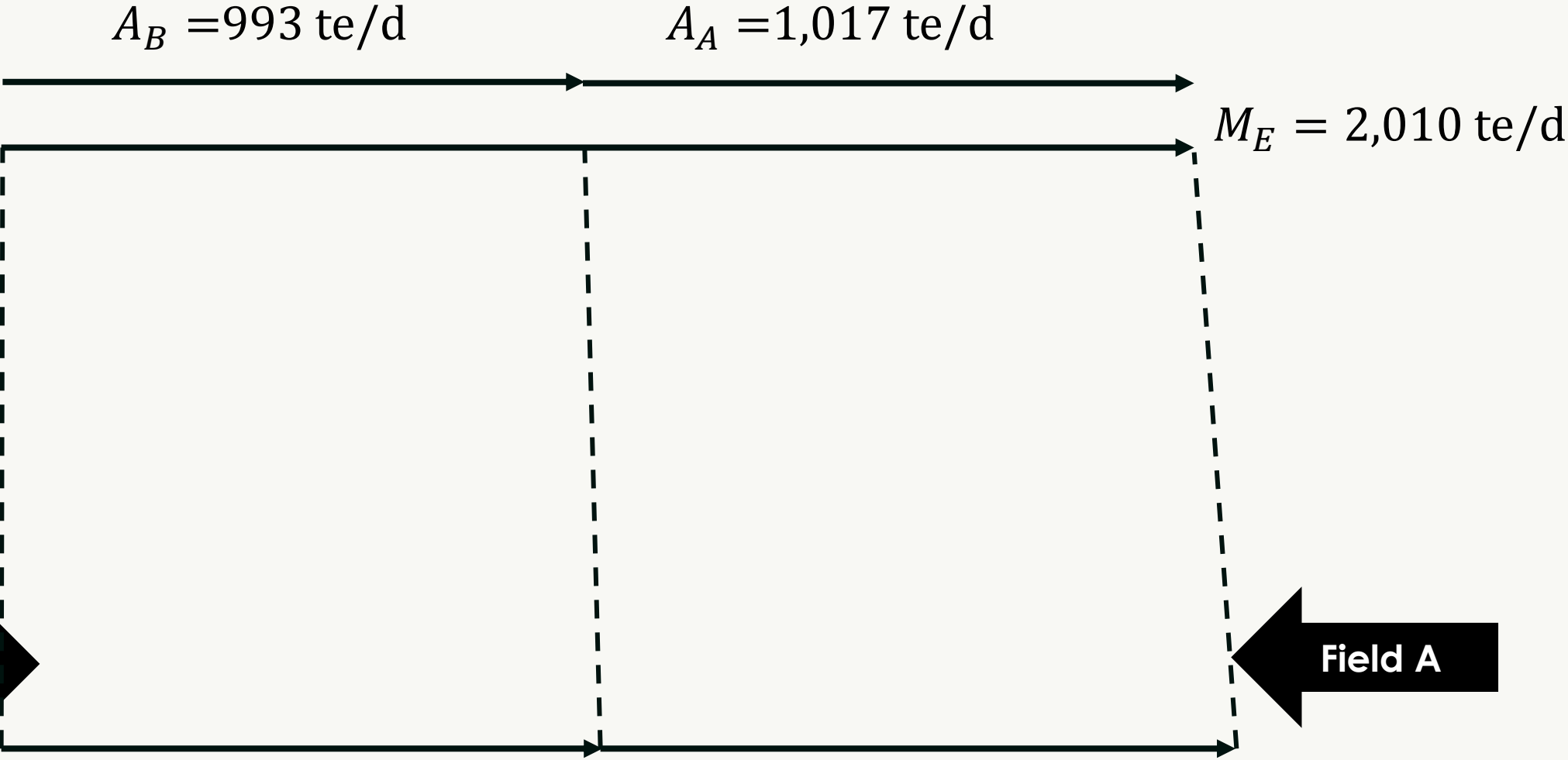
Steady production random uncertainty



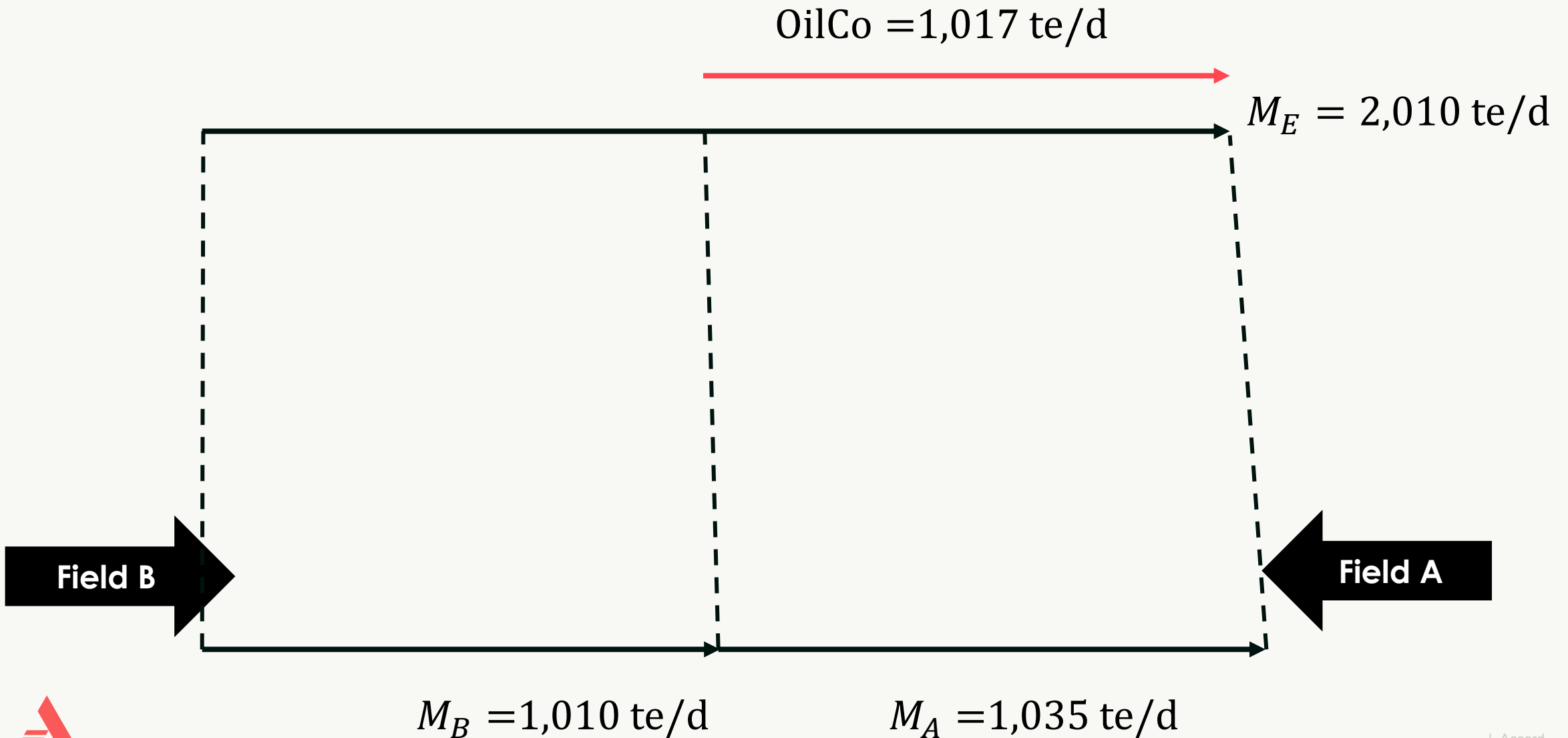
Steady production random uncertainty



Steady production random uncertainty



Oilco Allocation 100% Field A

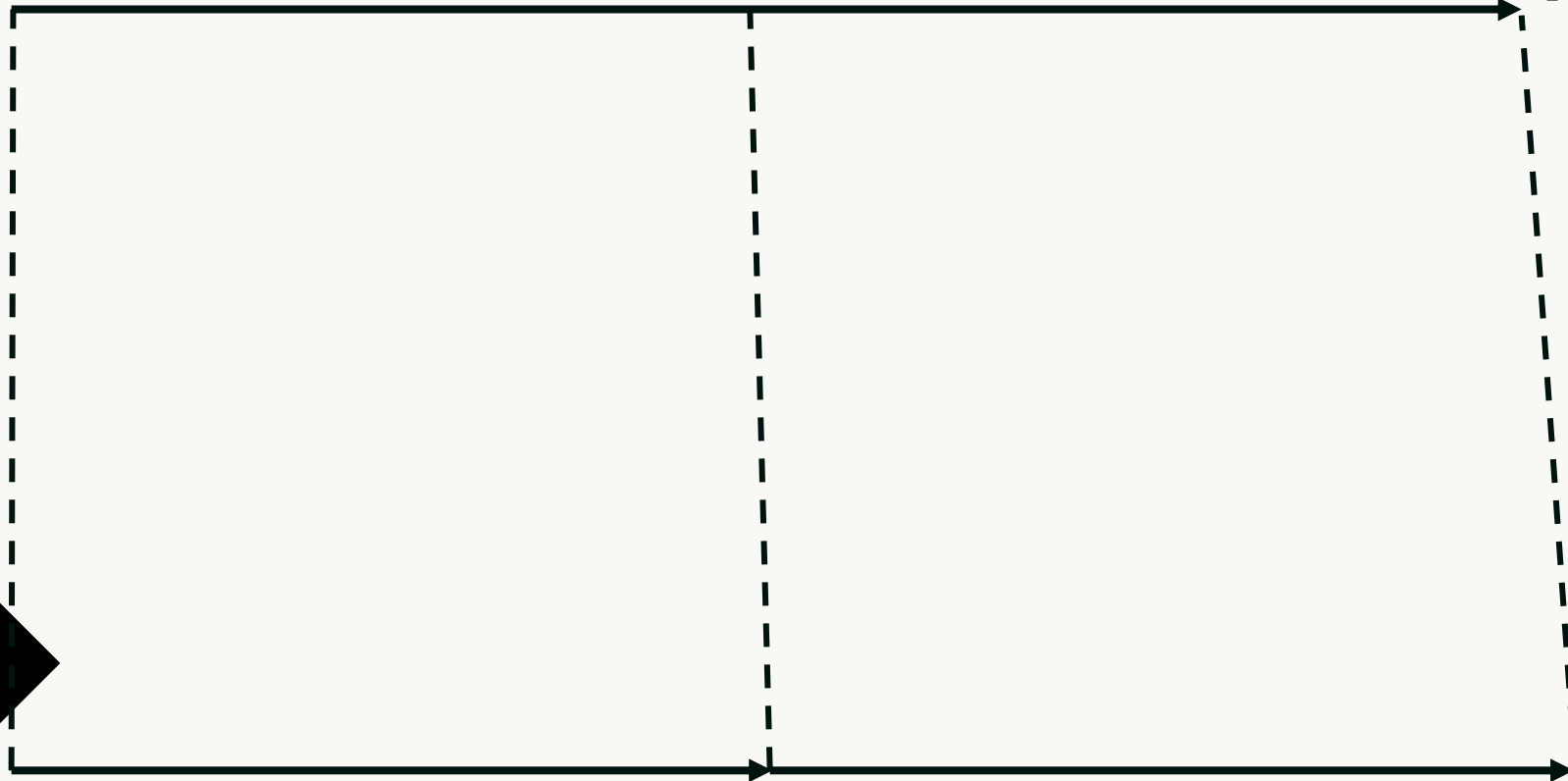


Oilco Allocation 50% Fields A & B

$$\text{OilCo} = 496 + 509 \text{ te/d}$$



$$M_E = 2,010 \text{ te/d}$$



$$M_B = 1,010 \text{ te/d}$$

$$M_A = 1,035 \text{ te/d}$$

Field B

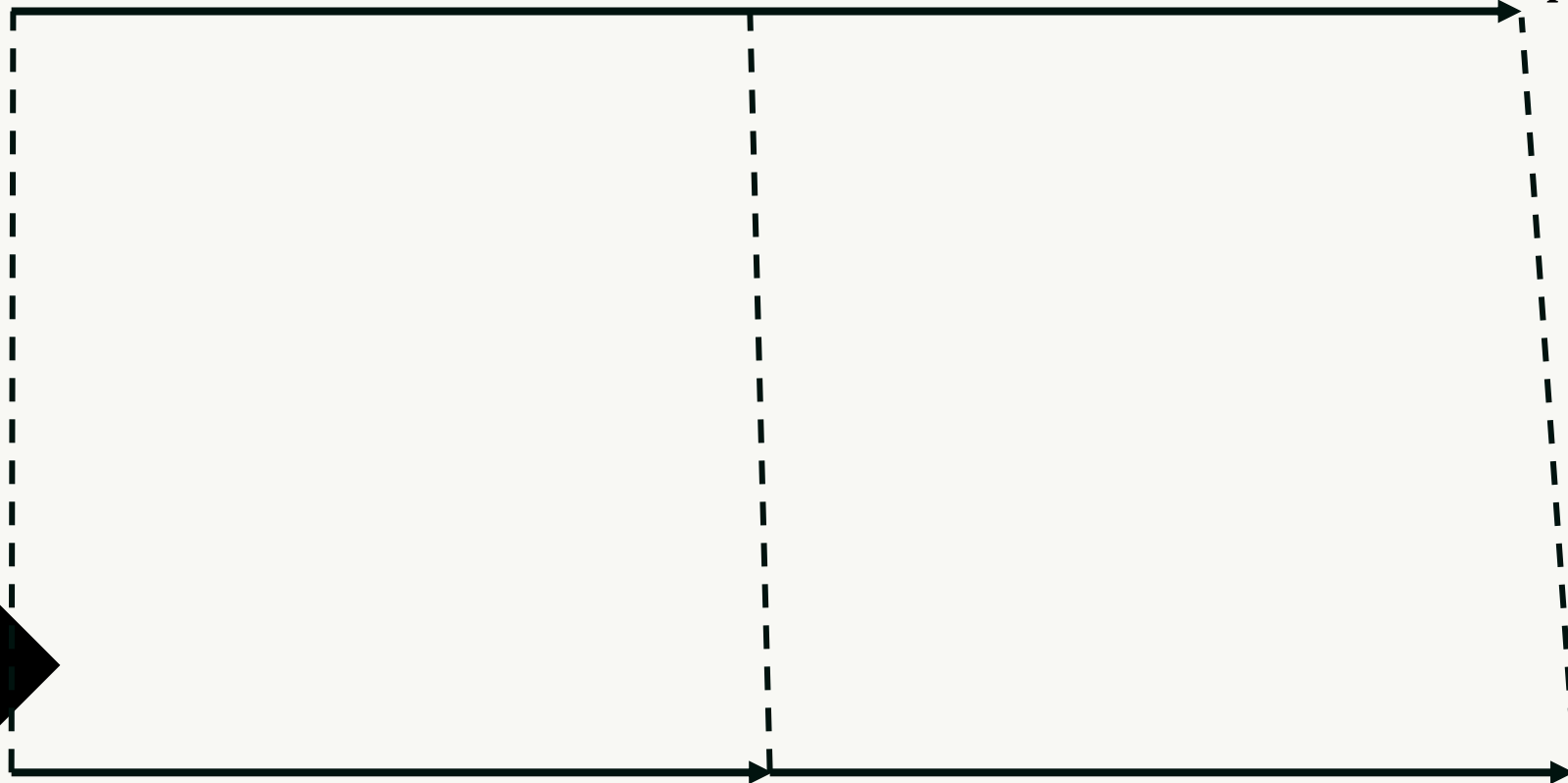
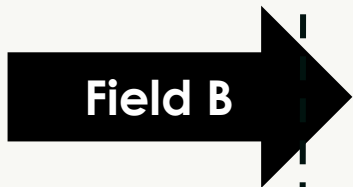
Field A



Oilco Allocation 50% Fields A & B

$$\text{OilCo} = 496 + 509 \text{ te/d} = 1,005 \text{ te/d}$$

$$M_E = 2,010 \text{ te/d}$$



$$M_B = 1,010 \text{ te/d}$$

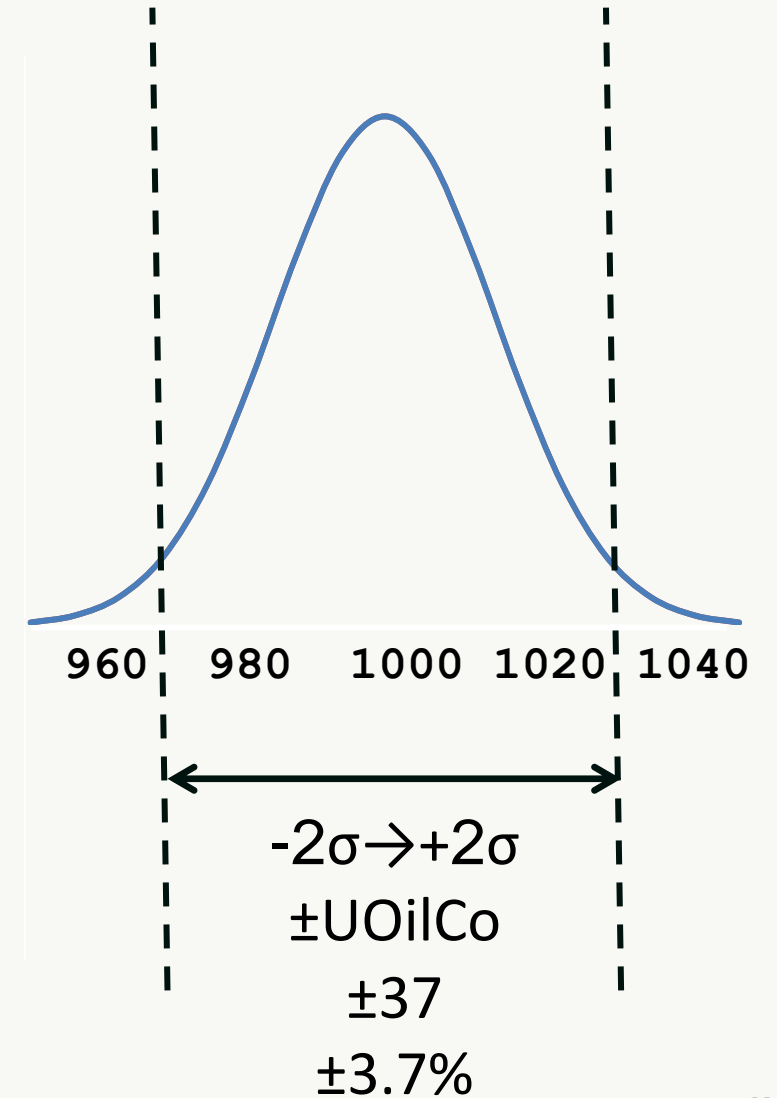
$$M_A = 1,035 \text{ te/d}$$





Monte Carlo

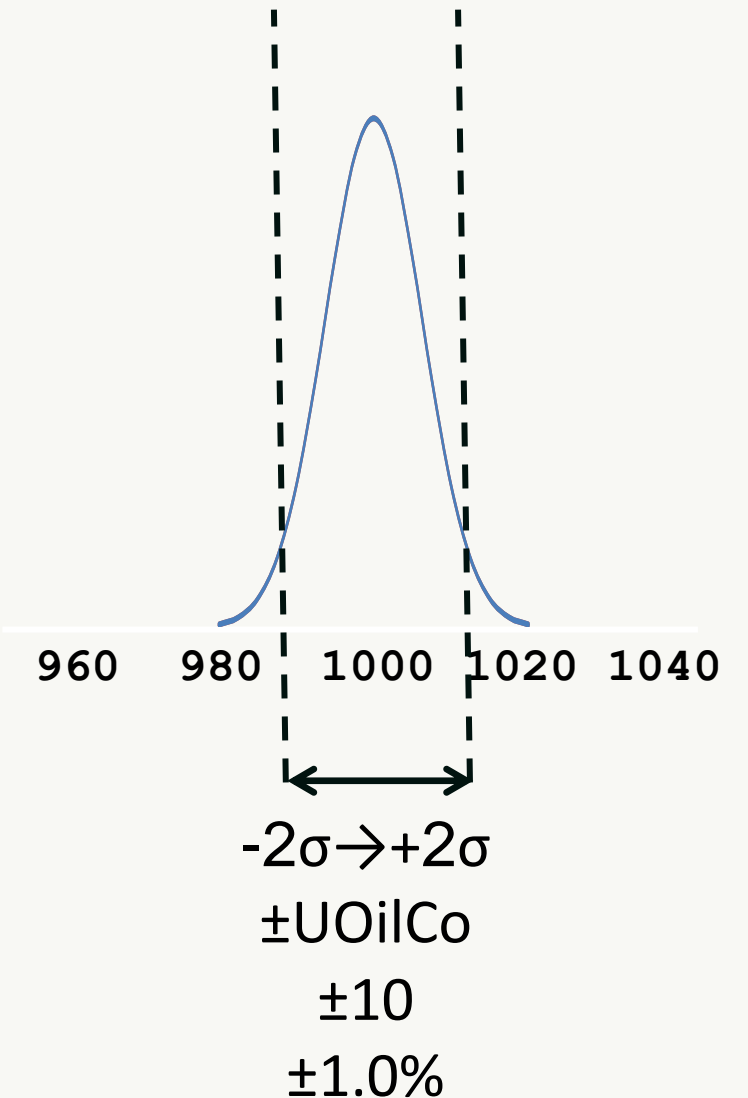
Iter	A	B	E	OilCo
	1000±5%	1000±5%	2000±1%	A

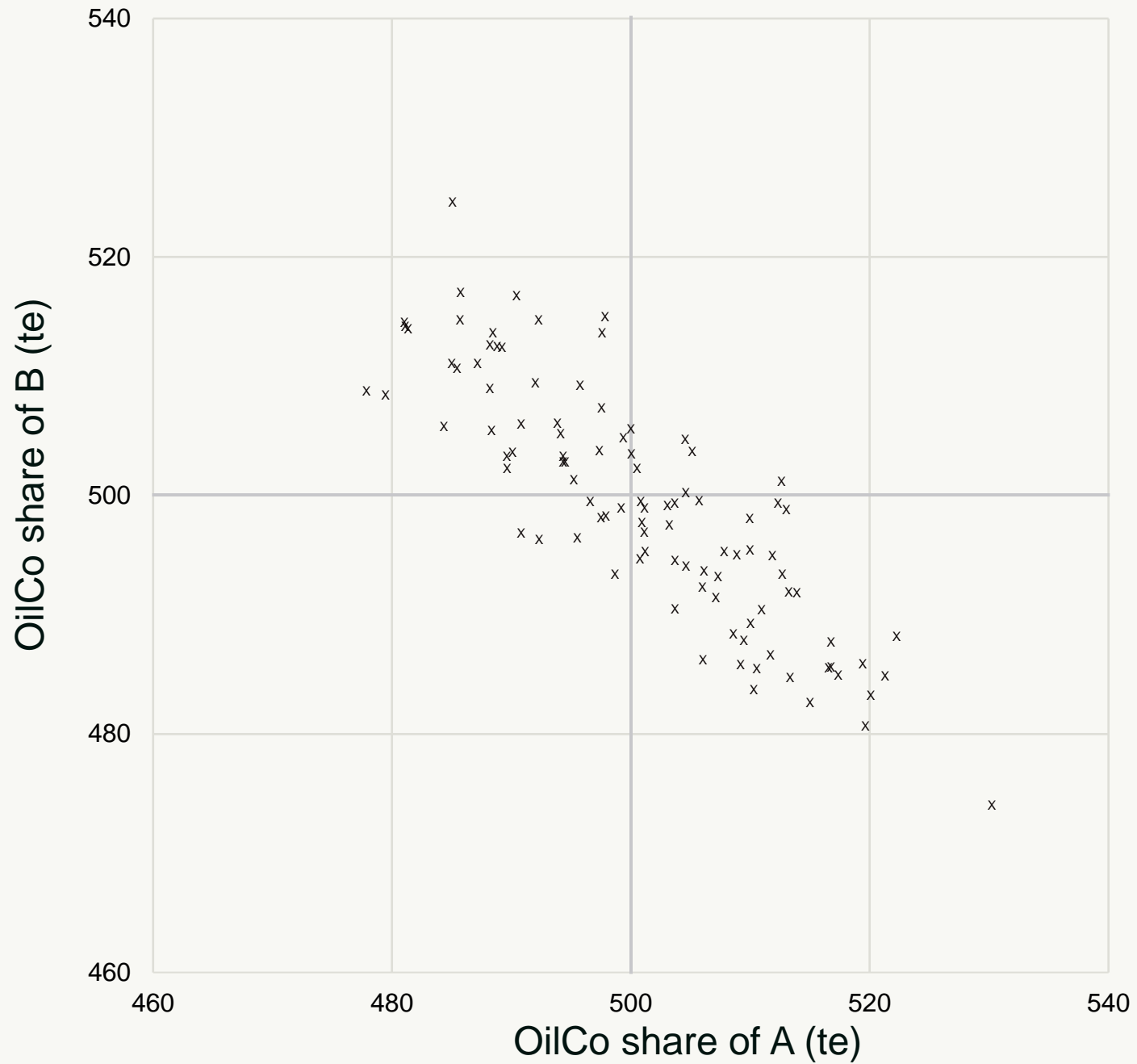




Monte Carlo

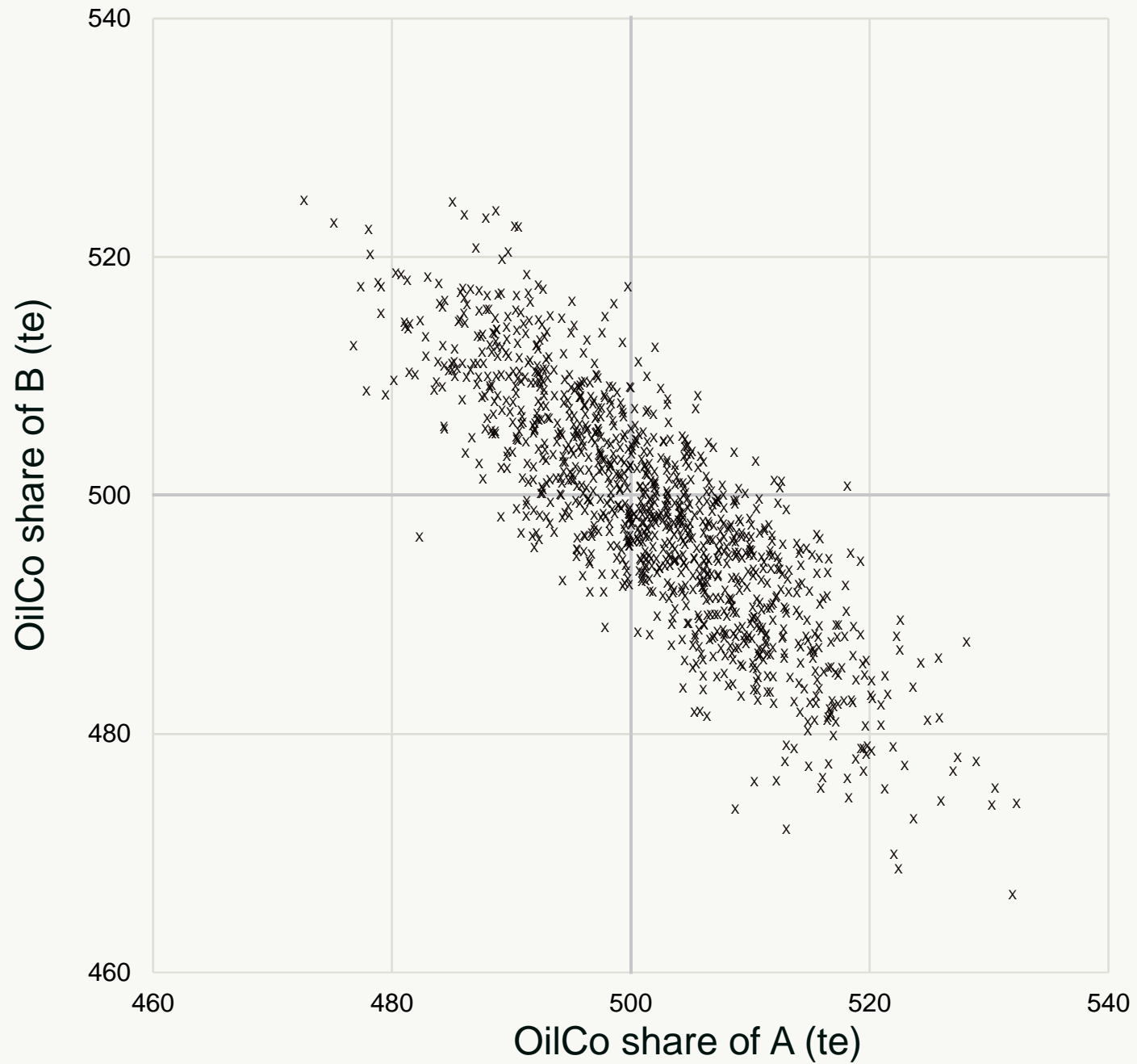
Iter	A	B	E	OilCo		
	1000±5%	1000±5%	2000±1%	A	B	Tot
1	1045	990	1994	512	485	997
2	1035	1010	2010	509	496	1005
3	983	1039	2009	488	516	1005
4	976	1010	2014	495	512	1007
5	1046	1041	1994	500	497	997
:	:	:	:	:	:	:
100	1005	987	1997	504	495	999





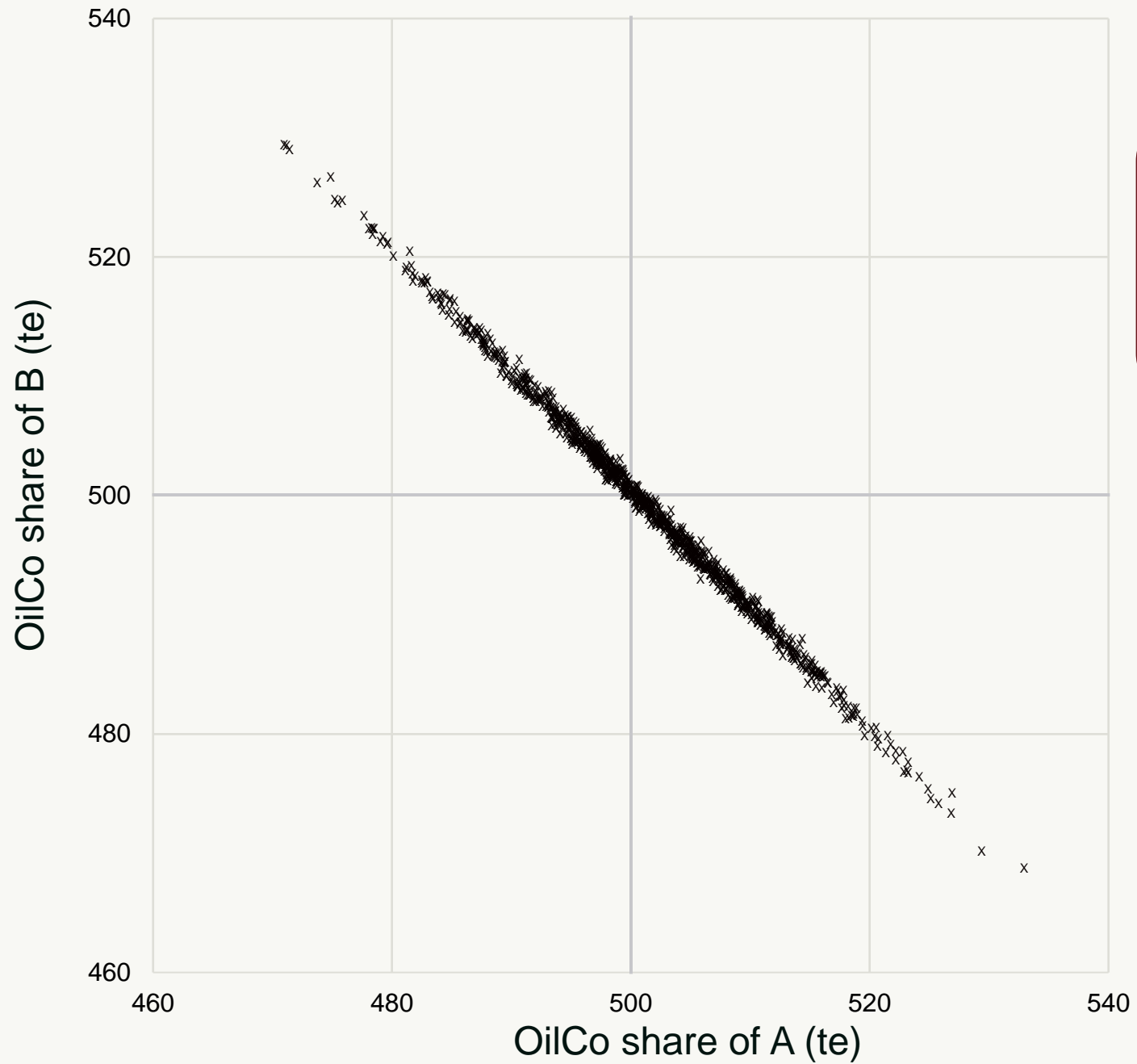
Platform Alpha





Platform Alpha



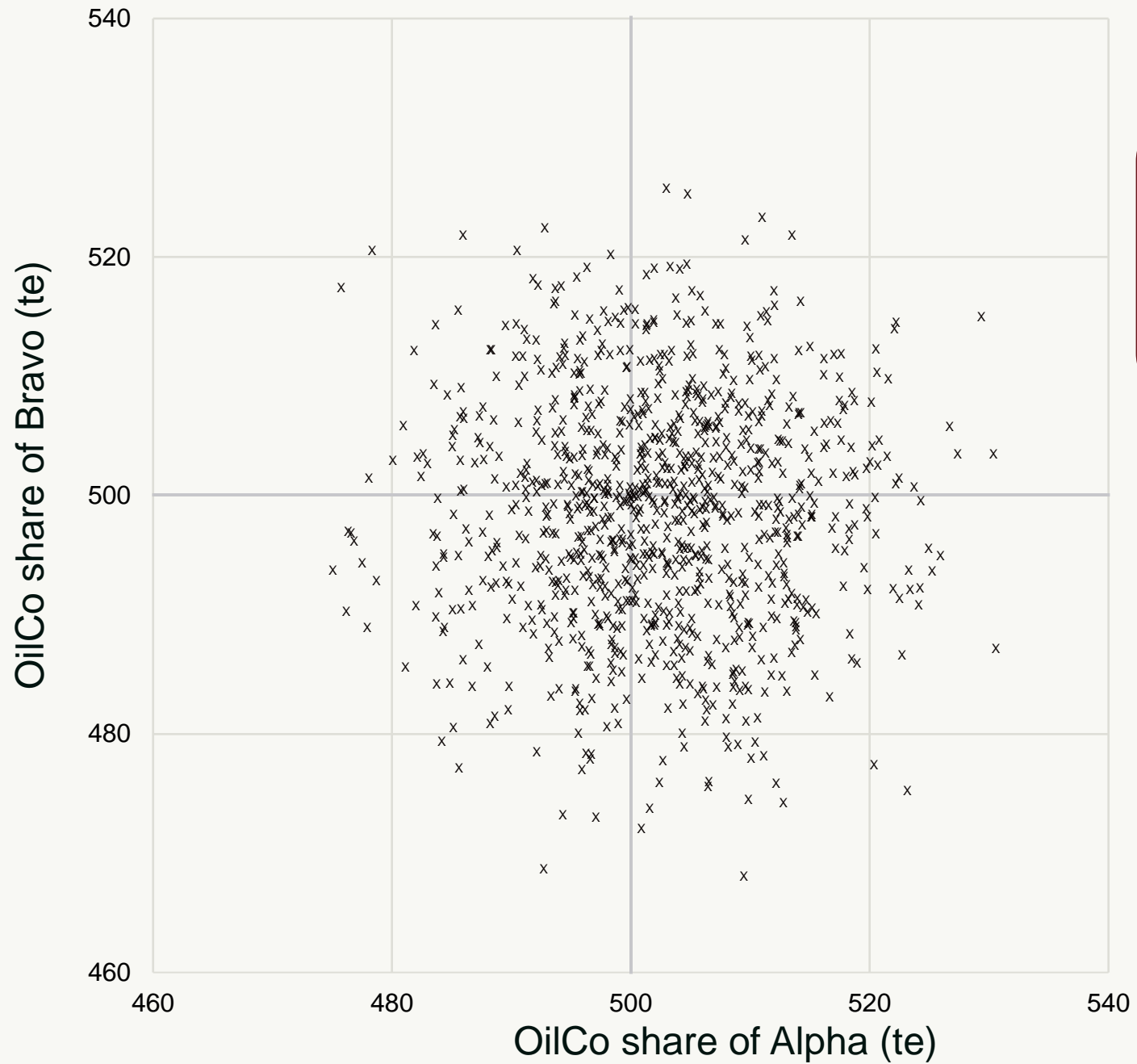


OilCo Allocation

Reduce Platform Alpha export metering uncertainty to $\pm 0.1\%$

Platform Alpha



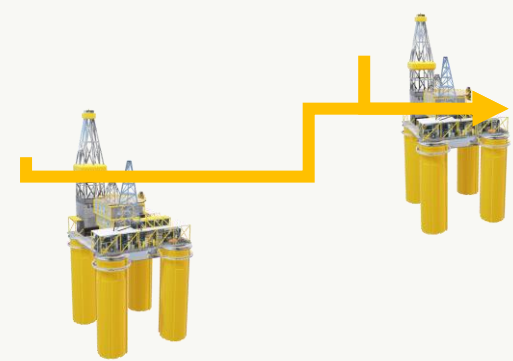


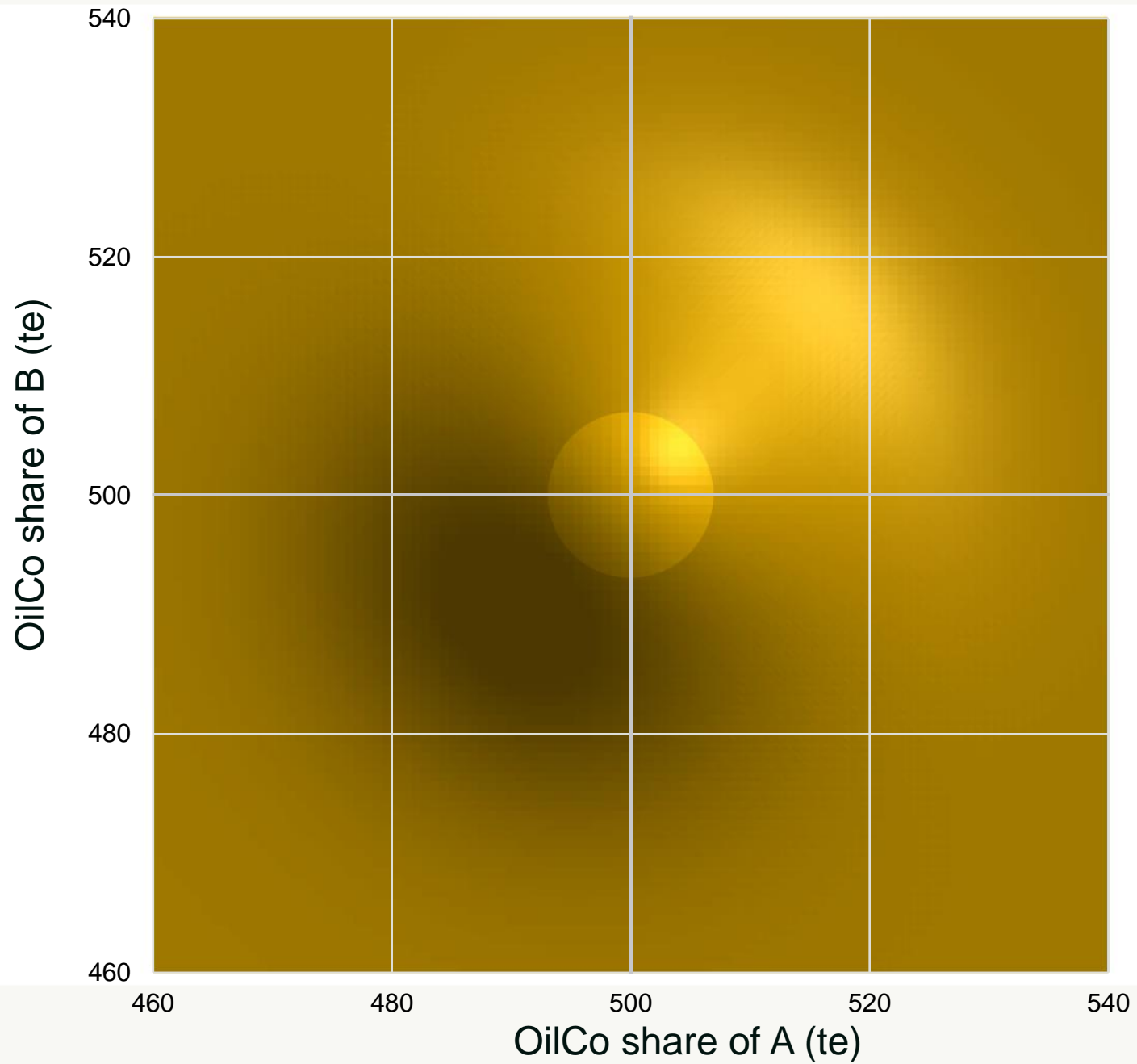
OilCo Allocation

Two platforms
allocated quantities
uncorrelated

Platform Bravo

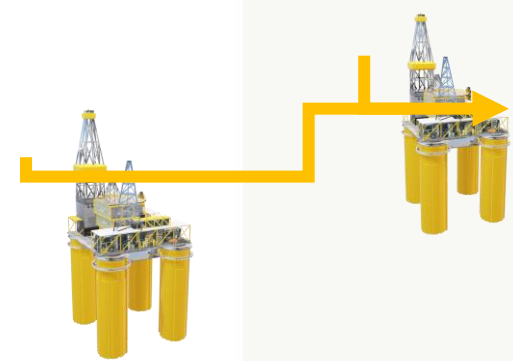
Platform Alpha

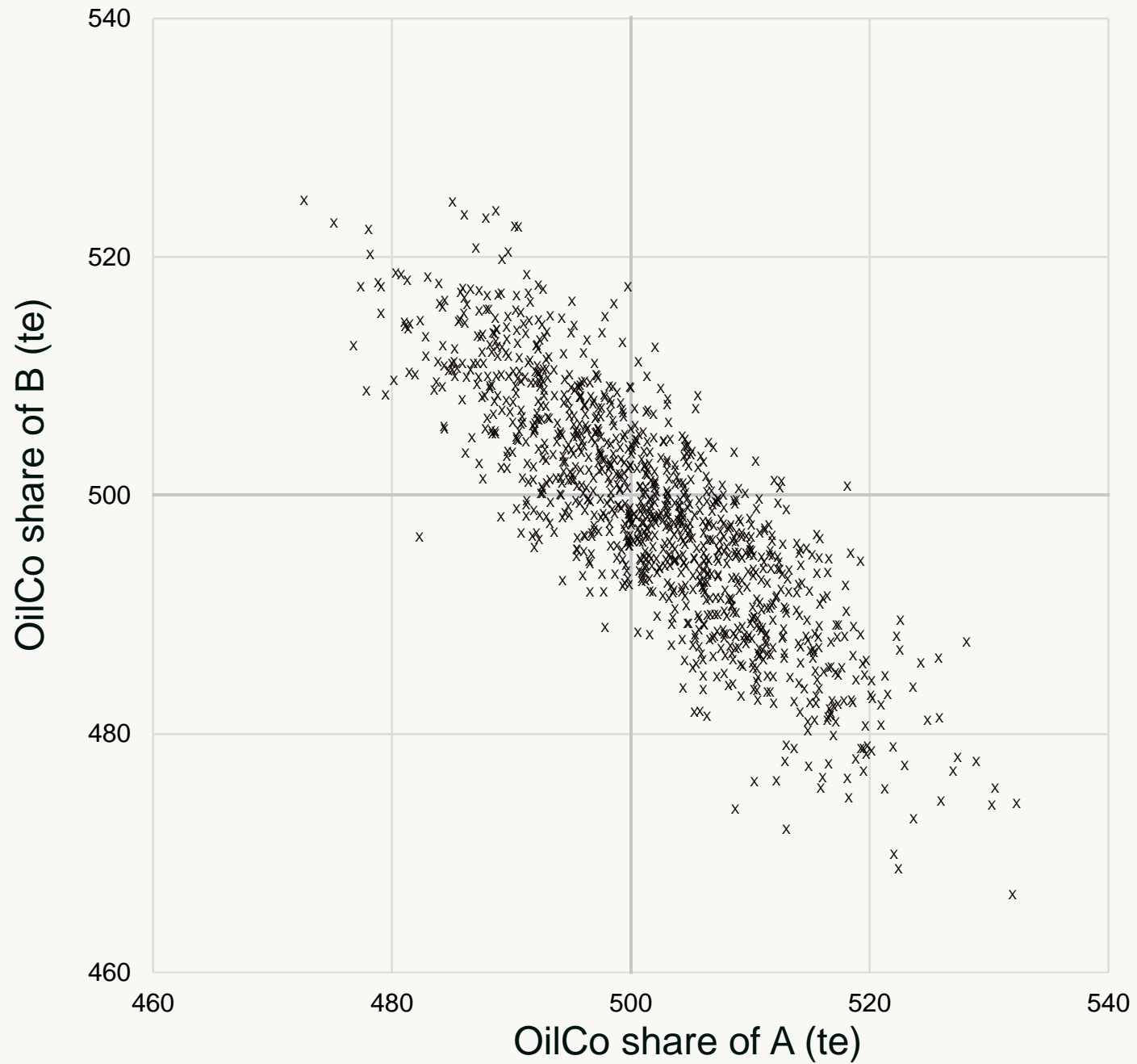




Platform Bravo

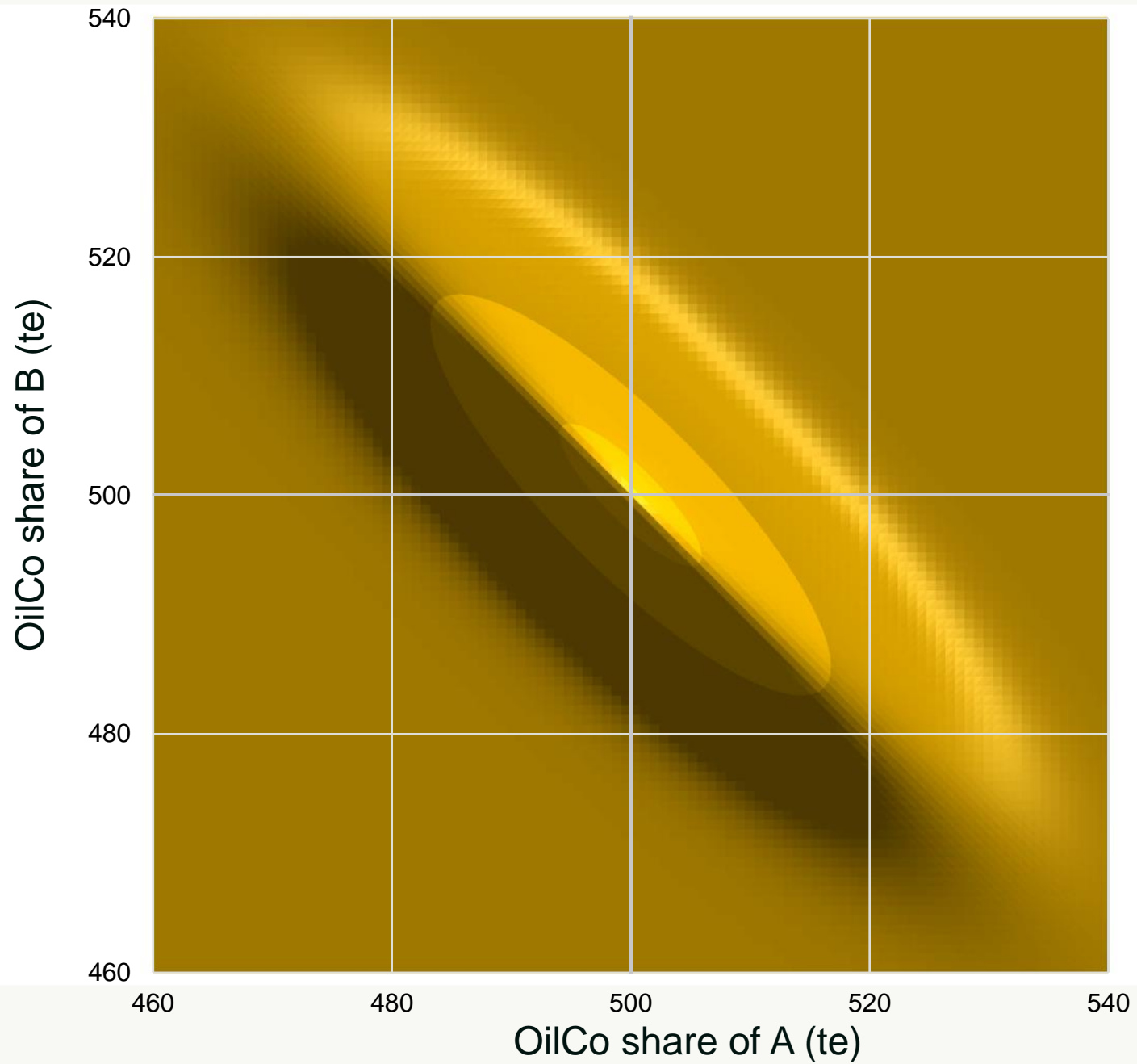
Platform Alpha





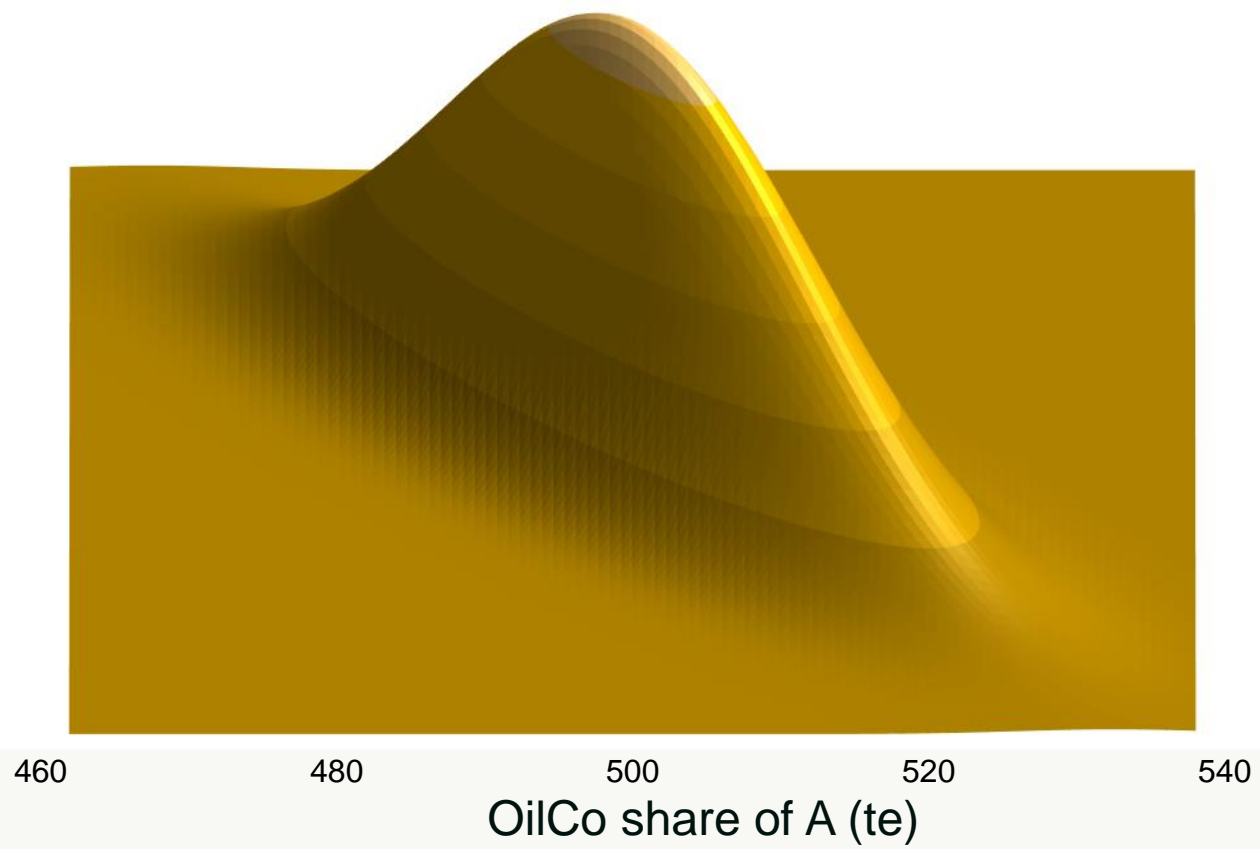
Platform Alpha





Platform Alpha





Platform Alpha





JCGM GUM-1:2023

**Guide to the expression of
uncertainty in measurement
— Part 1: Introduction**

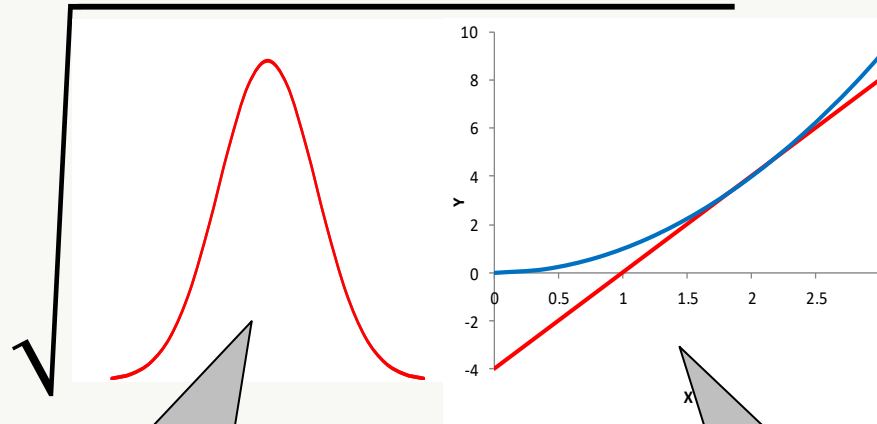
*Guide pour l'expression de l'incertitude de
mesure — Partie 1: Introduction*



Do the Maths

$$y = f(x_1, x_2, \dots, x_i, \dots, x_N)$$

$$Uy =$$



Absolute
Uncertainty
in y

Absolute
Uncertainties
in x_i 's

Sensitivity
coefficients

Platform Bravo



Platform Alpha



OilCo Allocation

Platform Alpha allocated 500 te/d $\pm 3.7\%$ (± 18 te/d)

Platform Bravo allocated 500 te/d $\pm 3.7\%$ (± 18 te/d)

Total allocated 1,000 te/d $\pm 2.6\%$ (± 26 te/d)

OilCo Allocation Two Platforms

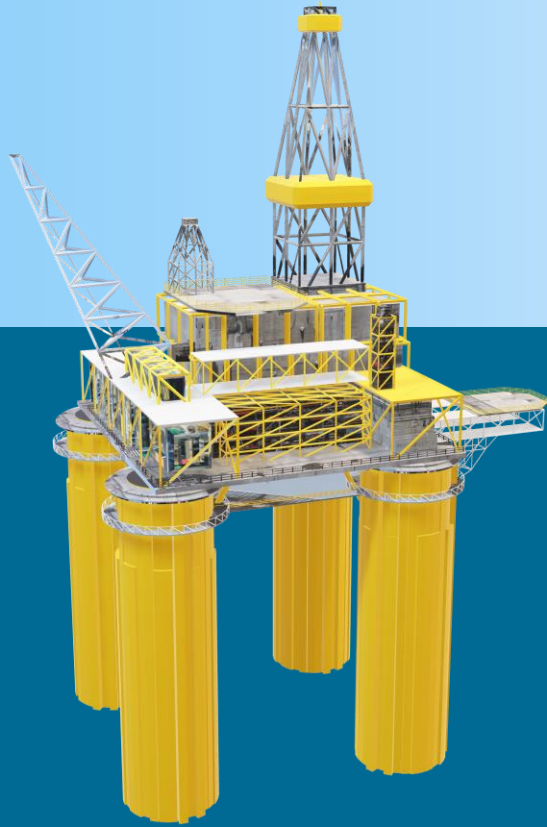


$$T = \alpha + \beta$$

$$U_T = \sqrt{U_\alpha^2 \left(\frac{\partial T}{\partial \alpha}\right)^2 + U_\beta^2 \left(\frac{\partial T}{\partial \beta}\right)^2} = 25.4$$

$$T = 1000 \pm 25.4 \text{ t/d} \quad (\pm 2.54\%)$$

Platform Alpha



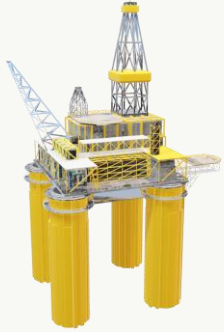
OilCo Allocation

Field A allocated 500 te $\pm 3.7\%$

Field B allocated 500 te $\pm 3.7\%$

Total 2,000 te $\pm 1\%$

OilCo Allocation One Platform, Two Fields



$$T = A + B$$

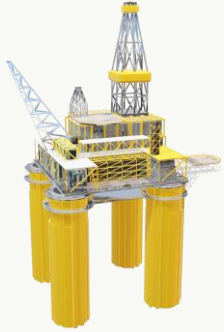
Covariance
terms

$$U_T = \sqrt{U_A^2 \left(\frac{\partial T}{\partial A}\right)^2 + U_B^2 \left(\frac{\partial T}{\partial B}\right)^2}$$

$$T = 1000 \pm 10 \text{ t/d} \quad (\pm 1.0\%)$$



OilCo Allocation One Platform, Two Fields



$$T = A + B$$

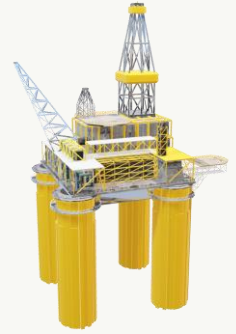
What is value of r ?

$$U_T = \sqrt{U_A^2 \left(\frac{\partial T}{\partial A}\right)^2 + U_B^2 \left(\frac{\partial T}{\partial B}\right)^2 + 2r_{A,B} U_A U_B \left(\frac{\partial T}{\partial A}\right) \left(\frac{\partial T}{\partial B}\right)}$$

$$T = 1000 \pm 10 \text{ t/d} \quad (\pm 1.0\%)$$



OilCo Allocation One Platform, Two Fields



$$U_T = \sqrt{U_\alpha^2 \left(\frac{\partial T}{\partial \alpha}\right)^2 + U_\beta^2 \left(\frac{\partial T}{\partial \beta}\right)^2 + 2r_{A,B} U_A U_B \left(\frac{\partial T}{\partial A}\right) \left(\frac{\partial T}{\partial B}\right)}$$

$$r = -0.852$$

$$U_T = \sqrt{18^2(1)^2 + 18^2(1)^2 - 2 * 0.852 * 18 * 18} = 10$$

$$T = 1000 \pm 10 \text{ t/d} \quad (\pm 1.0\%)$$



**34th International North Sea Flow Measurement Workshop
25-28 October 2016**

Technical Paper

**Analysis of Field and Ownership Allocation
Uncertainty in Complex Multi-field Configurations**

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Astrid Marie Skålvik¹
Armin Pobitzer¹
Eivind Nag Mosland¹
Camilla Sætre¹
Kjell-Eivind Frøysa^{1,2}**

**¹Christian Michelsen Research, Norway
²Bergen University College, Norway**



Re-Express Allocation – Independent Inputs

$$T = A + B$$

$$T = S_A M_E \left(\frac{M_A}{M_A + M_B} \right) + S_B M_E \left(\frac{M_B}{M_A + M_B} \right)$$

$$U_T = \sqrt{U_{M_E}^2 \left(\frac{\partial T}{\partial M_E} \right)^2 + U_{M_A}^2 \left(\frac{\partial T}{\partial M_A} \right)^2 + U_{M_B}^2 \left(\frac{\partial T}{\partial M_B} \right)^2}$$



Re-Express Allocation – Independent Inputs

$$U_T = \sqrt{U_{M_E}^2 \left(\frac{\partial T}{\partial M_E} \right)^2 + U_{M_A}^2 \left(\frac{\partial T}{\partial M_A} \right)^2 + U_{M_B}^2 \left(\frac{\partial T}{\partial M_B} \right)^2}$$

$$U_T = \sqrt{U_{M_E}^2 \left(S_A \left(\frac{M_A}{M_A + M_B} \right) + S_B \left(\frac{M_B}{M_A + M_B} \right) \right)^2 + U_{M_A}^2 \left(S_A - \left(S_A \left(\frac{M_A}{M_A + M_B} \right) + S_B \left(\frac{M_B}{M_A + M_B} \right) \right) \right)^2 + U_{M_B}^2 \left(S_B - \left(S_A \left(\frac{M_A}{M_A + M_B} \right) + S_B \left(\frac{M_B}{M_A + M_B} \right) \right) \right)^2}$$



Re-Express Allocation – Independent Inputs

$$U_T = \sqrt{U_{M_E}^2 \left(\frac{\partial T}{\partial M_E} \right)^2 + U_{M_A}^2 \left(\frac{\partial T}{\partial M_A} \right)^2 + U_{M_B}^2 \left(\frac{\partial T}{\partial M_B} \right)^2}$$

$$U_T = \sqrt{U_{M_E}^2 \left(S_A \left(\frac{M_A}{M_A + M_B} \right) + S_B \left(\frac{M_B}{M_A + M_B} \right) \right)^2 + U_{M_A}^2 \left(S_A - \left(S_A \left(\frac{M_A}{M_A + M_B} \right) + S_B \left(\frac{M_B}{M_A + M_B} \right) \right) \right)^2 + U_{M_B}^2 \left(S_B - \left(S_A \left(\frac{M_A}{M_A + M_B} \right) + S_B \left(\frac{M_B}{M_A + M_B} \right) \right) \right)^2}$$



Re-Express Allocation – Independent Inputs

$$S_A \left(\frac{M_A}{M_A + M_B} \right) + S_B \left(\frac{M_B}{M_A + M_B} \right)$$

$$U_T = \sqrt{U_{M_E}^2 x_{OilCo}^2 + U_{M_A}^2 (S_A - x_{OilCo})^2 + U_{M_B}^2 (S_B - x_{OilCo})^2}$$

OilCo's share of total production



OilCo 50% Share in Fields A and B

$$x_{OilCo} = 0.5$$

$$U_T = \sqrt{20^2 \cdot 0.5^2 + \dots}$$

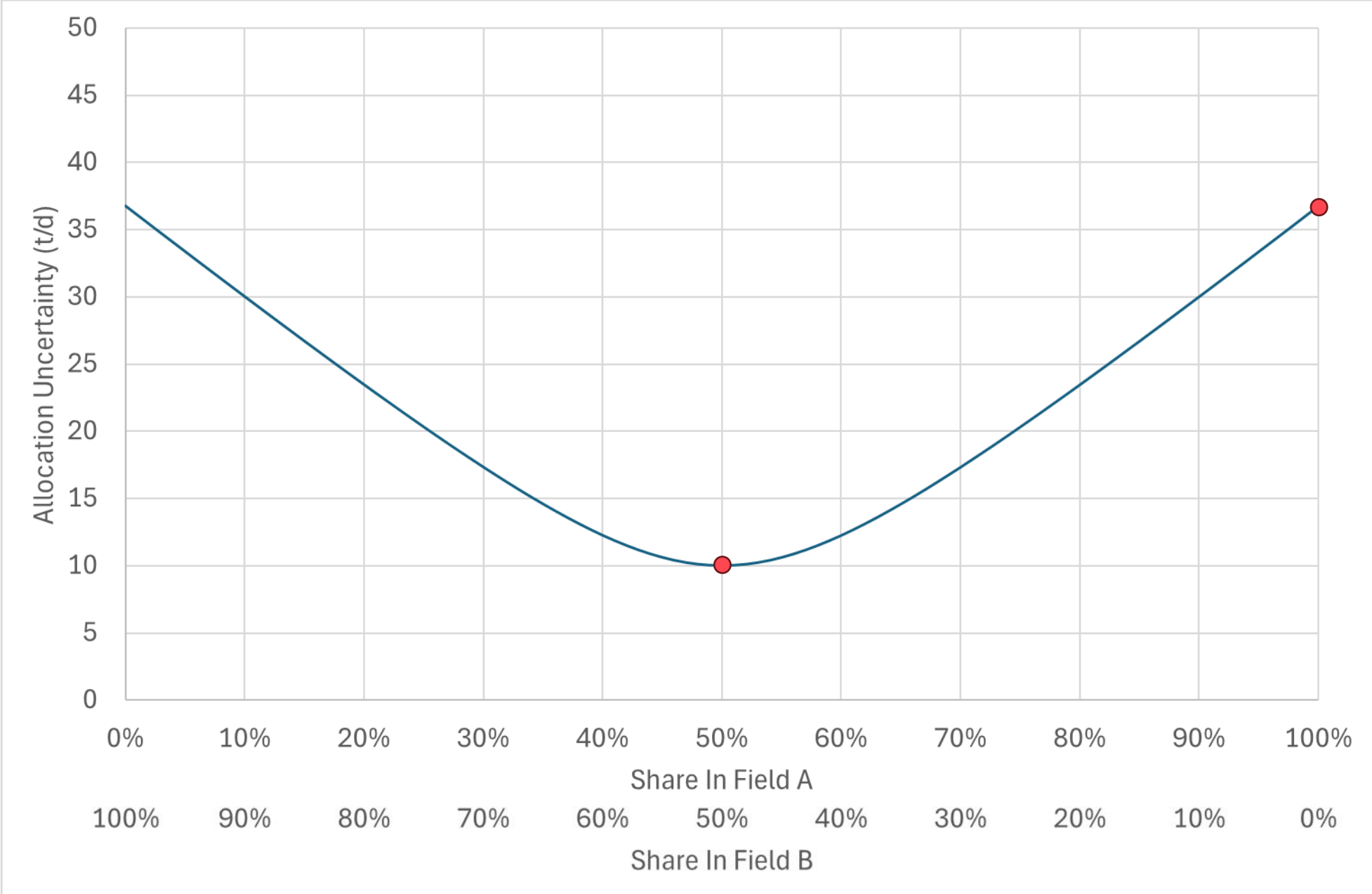


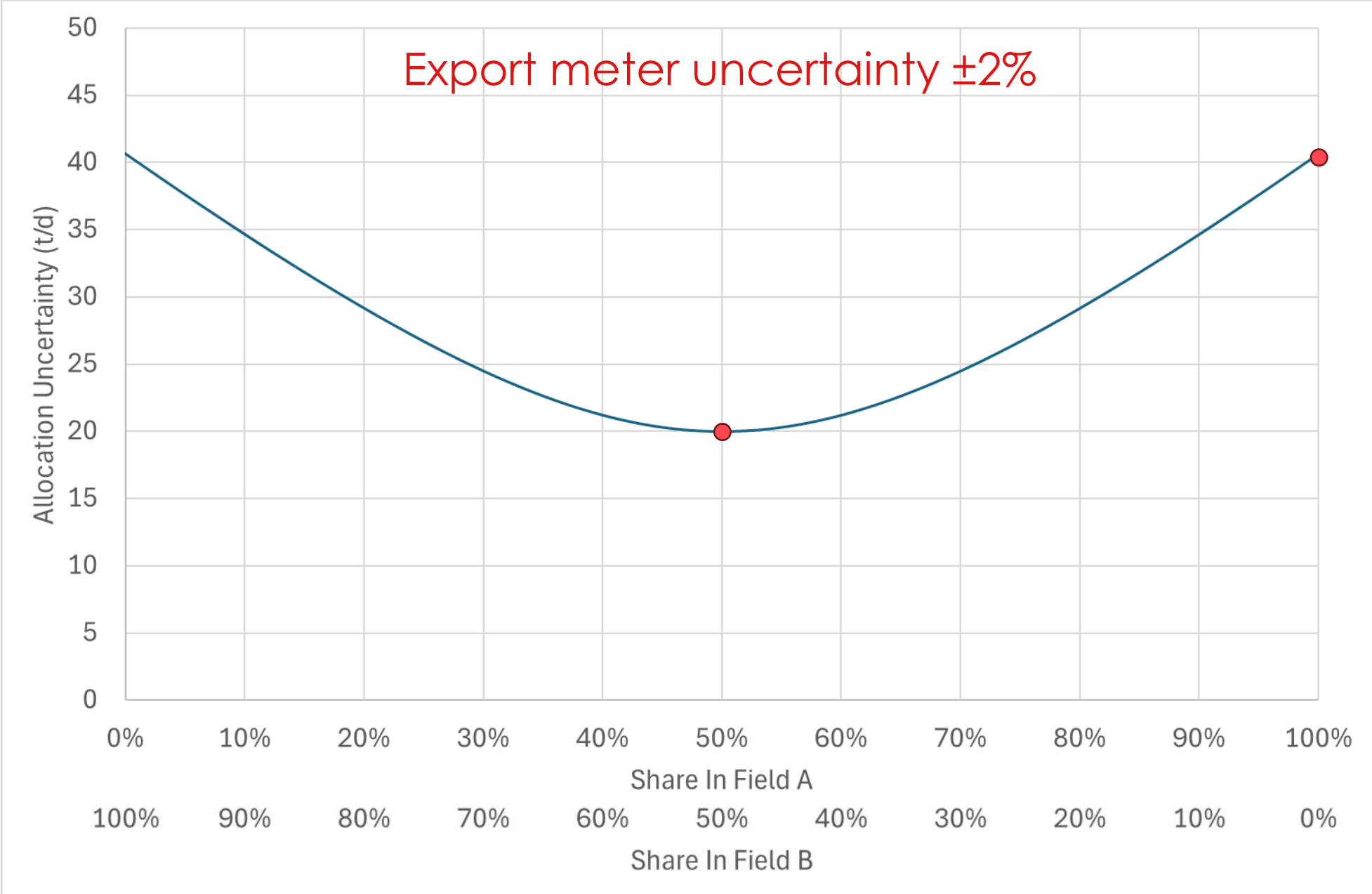
OilCo 100% Share in Field A only

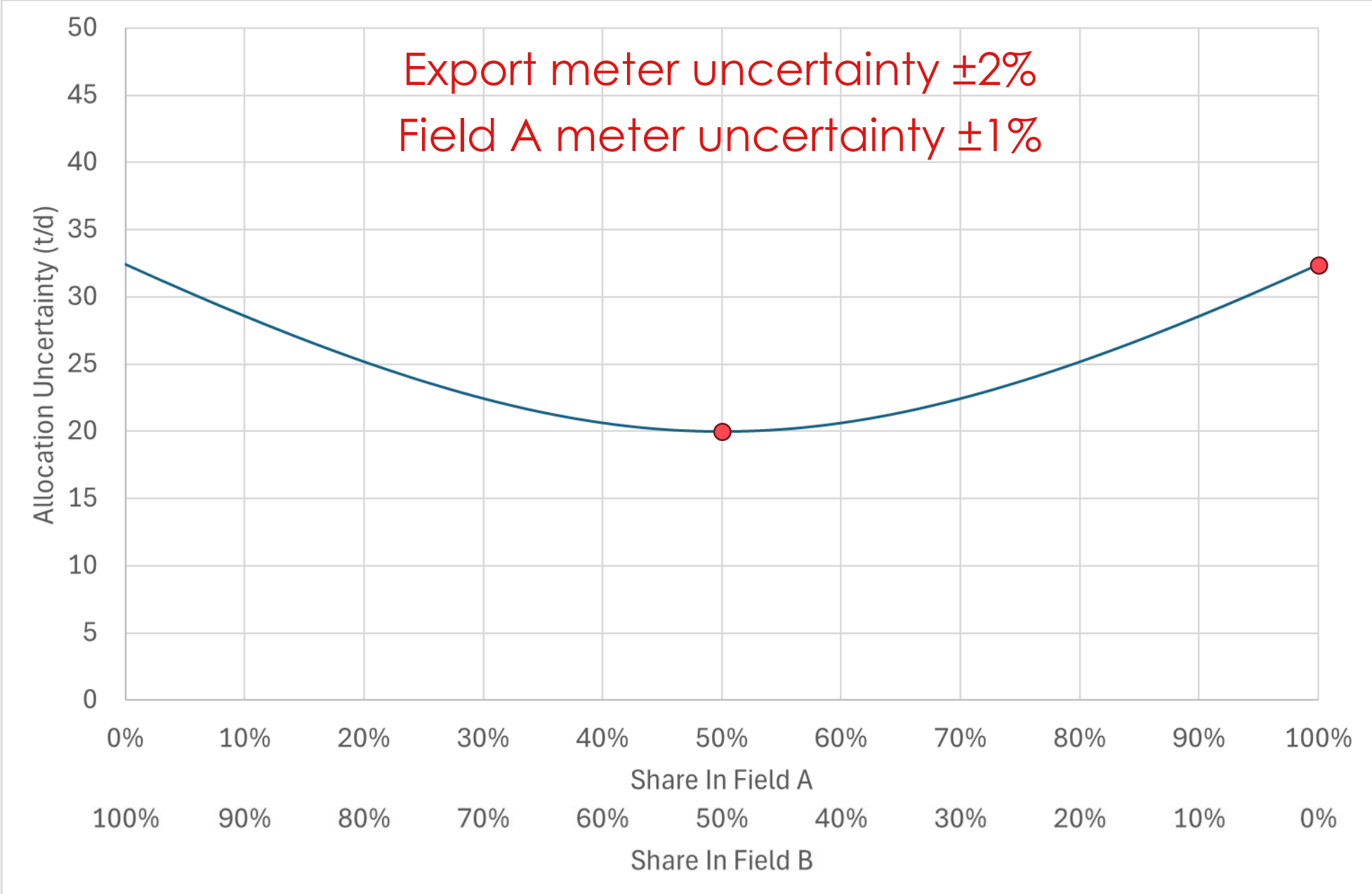
$$x_{OilCo} = 0.5$$

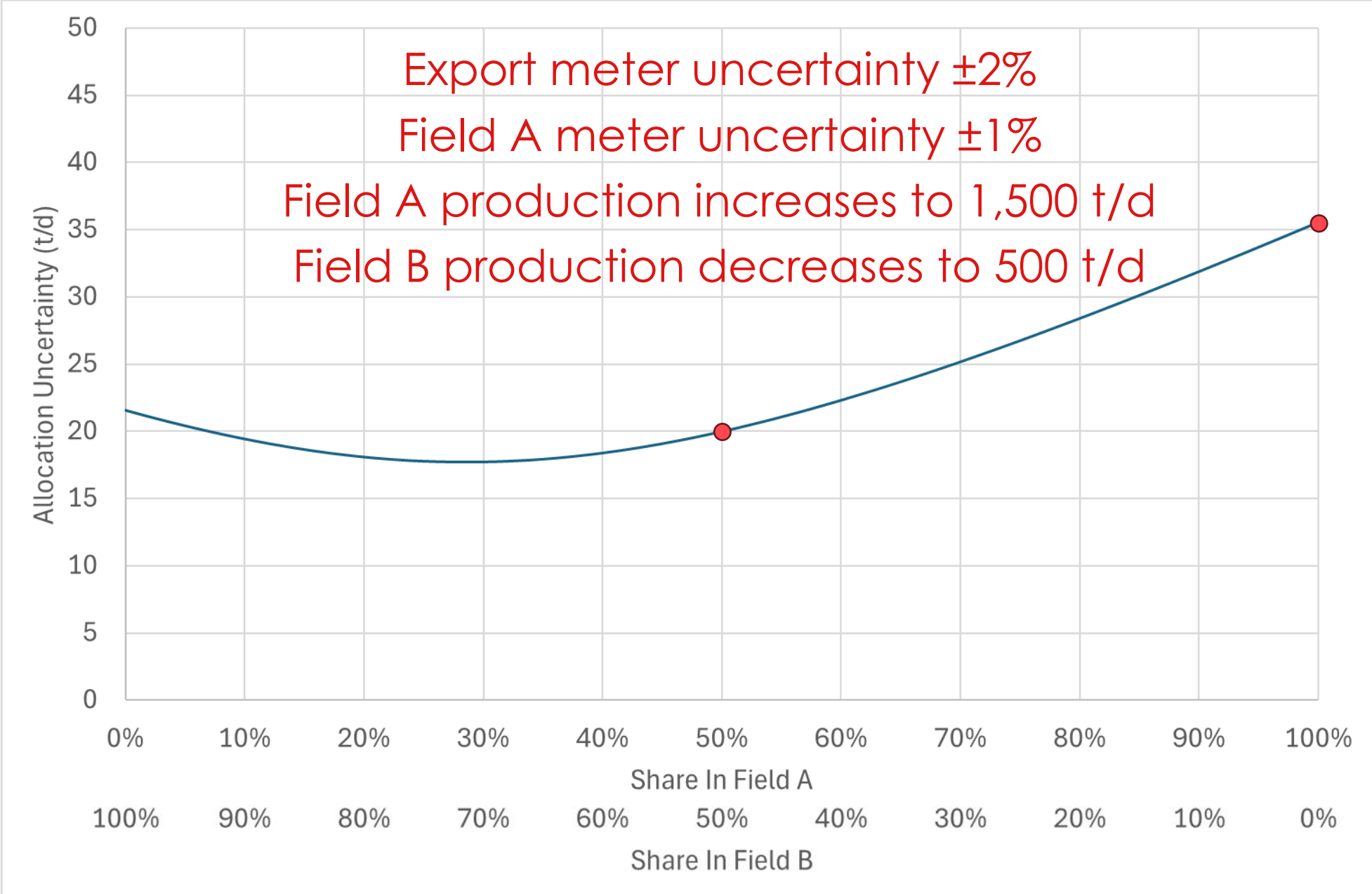
$$U_T = \sqrt{20^2 \cdot 0.5^2 + 50^2(1 - 0.5)^2 + 50^2(0 - 0.5)^2}$$



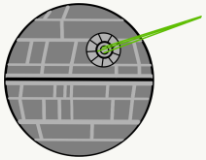








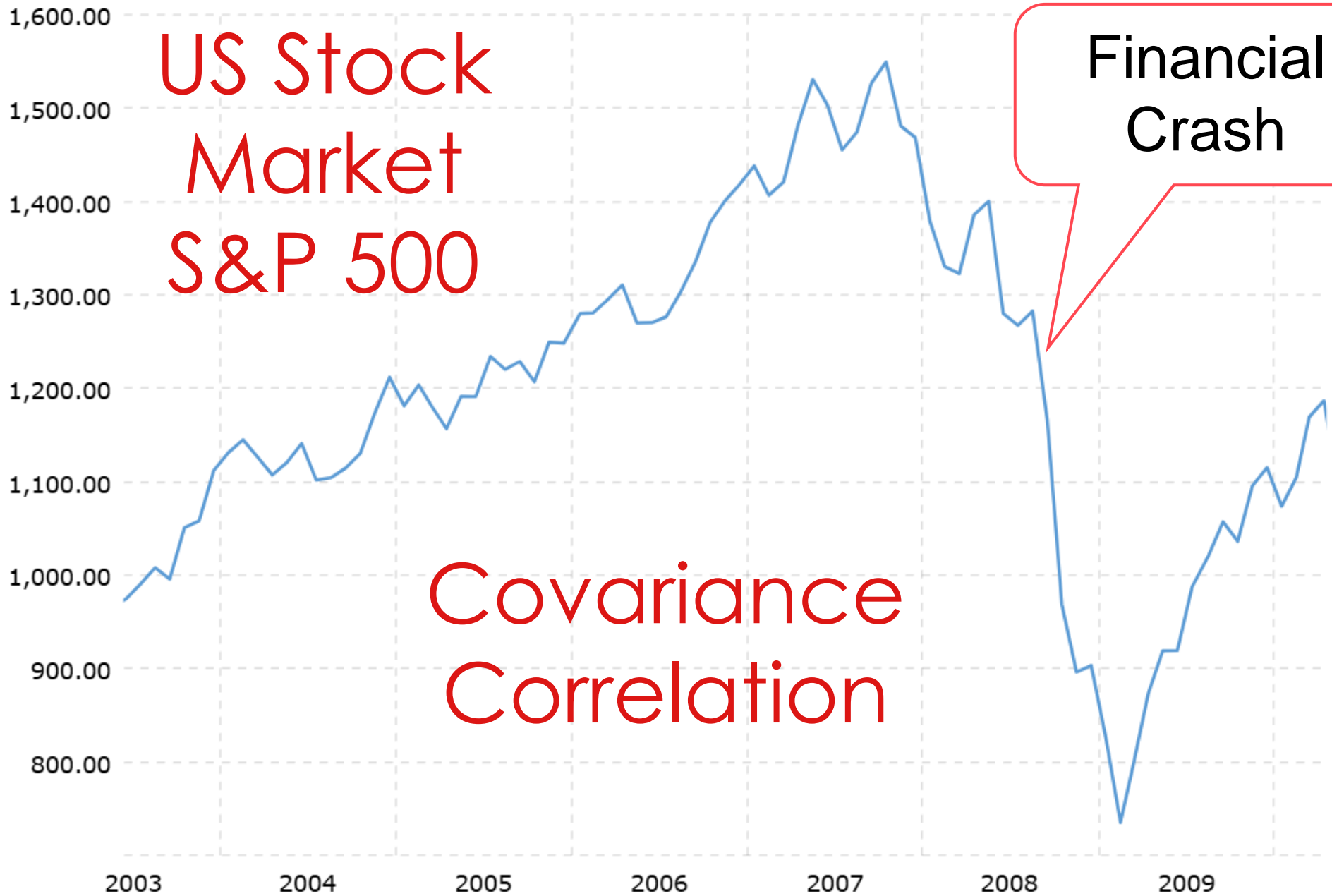
Multiple fields and companies



	Equinox	Jurassic	LV 246	Orion	Alderaan
OilCo	35%	65%	52%	52%	30%

	Equinox	Jurassic	LV 246	Orion	Alderaan	Export
Flows (t/d)	1000	2000	500	800	150	4450
Unc Rel ±	6%	4%	2%	5%	10%	1%

	Allocation (t/d)	Flow Fraction
OilCo	2371	53%
Weyland Yutani	605	14%
Ingen	1210	27%
Death Star Inc	128	3%
Tyrell Corporation	136	3%



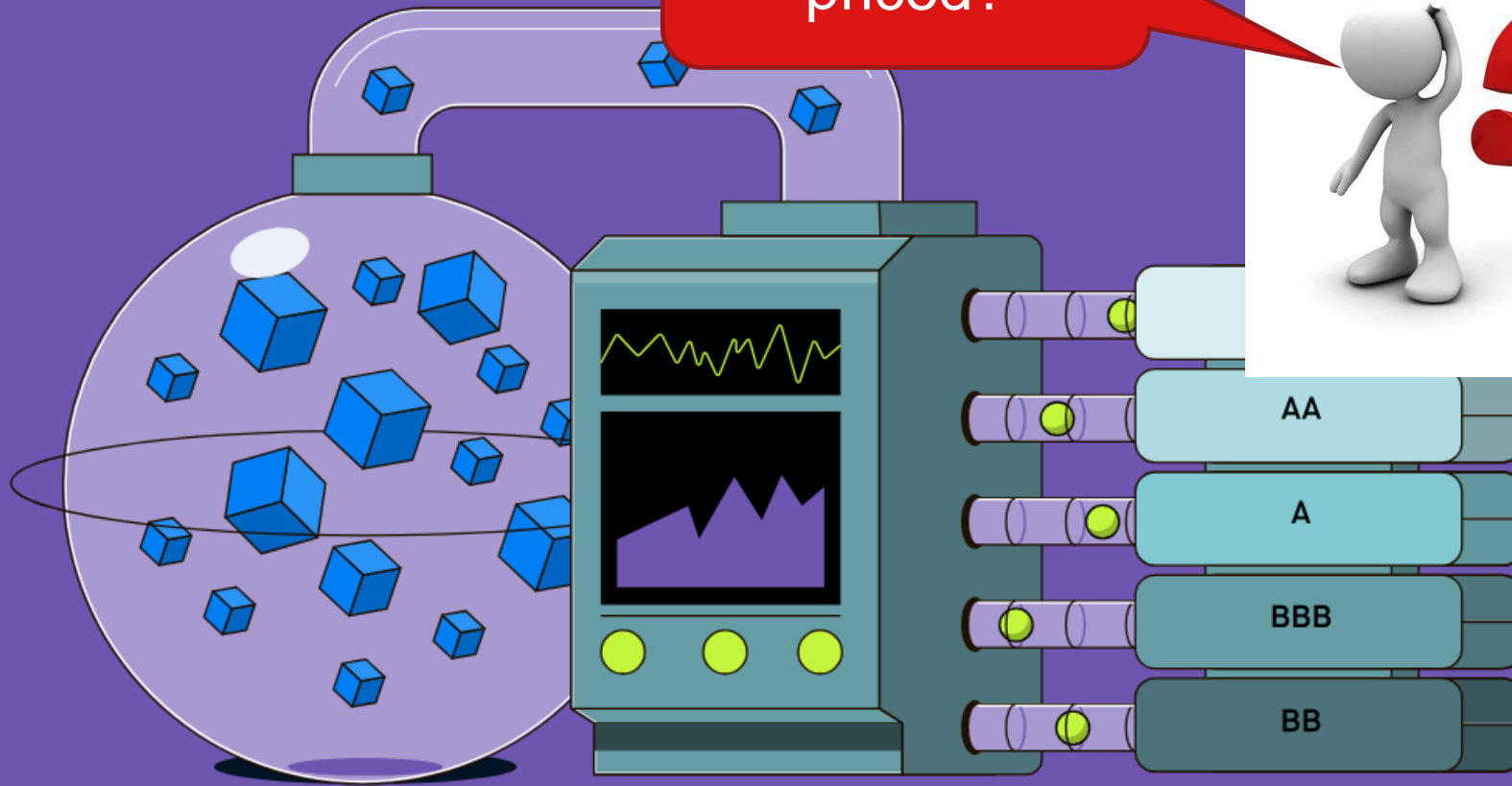
US Stock
Market
S&P 500

Financial
Crash

Covariance
Correlation



How are these priced?



Types of Debt

Credit Card Debt, Auto Loans, Mortgages, Corporate Bonds

Financial Firms

Package and sell debts as CDOs

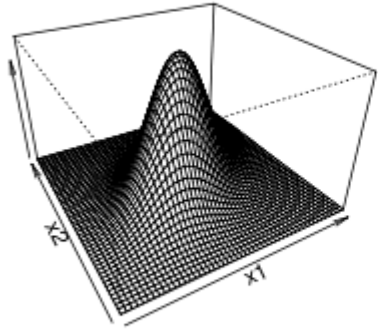
Investment Grades

Higher investment grades carry less risk and potential gain, while lower investment grades carry higher risk and potential gain

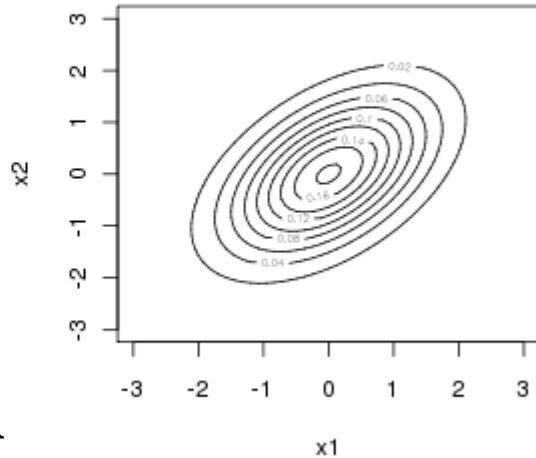


Bivariate Normal Distribution (rho=0.5)

Density



Contour



Gaussian Copula

In 2006 the CDO market was valued at nearly 2 trillion dollars
\$2,000,000,000,000

Other copulas are available!



$$C_g(u, v, \rho) = \int_{-\infty}^{\Phi^{-1}(u)} \int_{-\infty}^{\Phi^{-1}(v)} \frac{1}{\sqrt{1-\rho^2}} e^{\frac{\rho(x^2-2xy+y^2)}{2(1-\rho^2)}} dx dy$$

FELIX SALMON BUSINESS FEB 23, 2009 12:00 PM

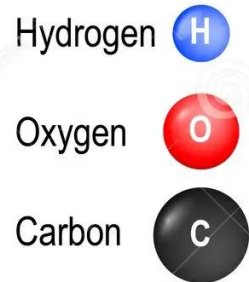
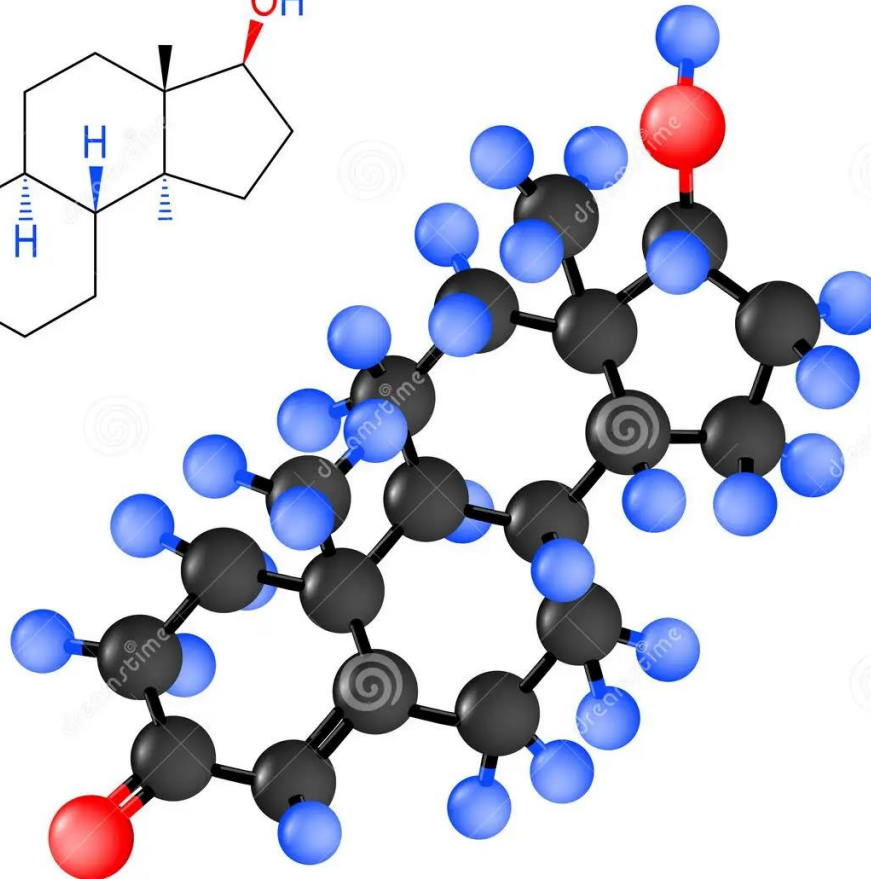
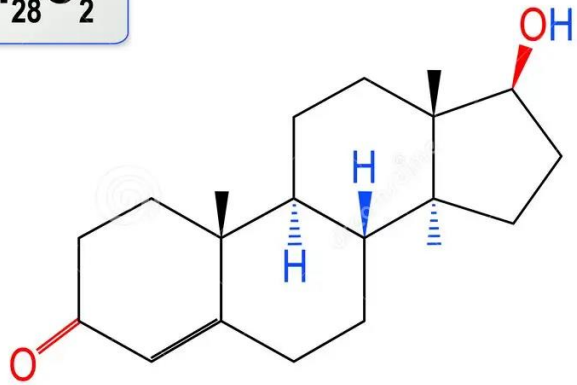
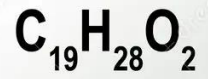
Recipe for Disaster: The Formula That Killed Wall Street

In the mid-'80s, Wall Street turned to the quants—briny financial engineers—to invent new ways to boost profits.



WIRED





1920's

1929

1929 - 1940

1960's

1970's

1980's

1987

1990's

2008



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